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ABSTRACT

Included in this report on the third conference on federal research and development (R&D) budgeting are the texts of the prepared presentations and summaries of the discussions that followed. Opinions and recommendations are presented on topics such as the level and focus of R&D in industry, the rate of innovation in the United States, the U.S. technological position in the world, the focus of government R&D, the effects of government regulations on industry investment decisions, and the relationship between R&D and the economy. (BB)

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AAAS Committee on Science, Engineering, and Public Policy

R&D in the Federal Budget

R&D, Industry, & the Economy

Colloquium Proceedings
June 20-21, 1978

Edited by
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U.S. DEPARTMENT OF HEALTH
EDUCATION & WELFARE
NATIONAL INSTITUTE OF
EDUCATION

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Introduction

Three years ago, with encouragement from the Sloan Foundation, AAAS set out to test its ability to produce an annual analytic report on research and development in the federal budget and to sponsor a mid-year colloquium on R&D policy. This idea was premised on the view that the budgeting process was the key to the government's decision-making and priority-setting behavior for research and development. If the budgeting process could be demystified and tracked over time, the quality and consequences of R&D budget decisions could be examined and alternatives put forward by interested members of the scientific and technical communities. As a window on the anatomy of science policy, the budget process had no peer.

The AAAS R&D Budget Project has remained in an experimental mode. Each year a different set of institutional problems has been addressed in the context of the federal budget for research and development. The third in the series of annual reports and colloquia* continues the analyses and discussions of R&D policies and programs in the President's budget, but in addition, goes beyond the confines of the federal budget to examine funding and problems of R&D in industry and the impact of R&D, government and private, on the economy. The broader scope is intended both to recognize the vital importance of industry R&D and of R&D to the economy and to give a better reflection of the full range of AAAS interest in R&D and science and technology policy.

The third annual AAAS Colloquium on R&D Policy brought together almost 300 leaders of the scientific and technological communities, responsible decision-makers in the executive and legislative branches of government, and representatives of the media for frank and open discussion. Frank Press, Director of the White House Office of Science and Technology Policy, set the stage for the conference in his keynote address by elucidating many of the key R&D policy issues that fall within the purview of the four discussion sessions: "Federal R&D," "R&D in Industry," "R&D and international Economic Competition," and "R&D and the Economy." Addresses by distinguished representatives from the Executive Office of the President, Congress, the Department of Commerce, industry, and academia raised additional issues for consideration by the group. To initiate and guide the discussions a panel of inquiry was present throughout the colloquium.

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*Research and Development: AAAS Report III, as well as the two previous reports and colloquia proceedings can be obtained from AAAS.

These Proceedings include the texts of the prepared presentations and summaries of the discussions that followed. The reader will find opinions and recommendations on topics such as the level and focus of R&D in industry, the rate of innovation in the U.S., the U.S. technological position in the world, the focus of government R&D, the effects of government regulations on industry investment decisions, and the relationship between R&D and the economy. Many of these issues are related to some of the nation's most pressing problems--inflation, productivity decline, balance of trade--and they are currently being examined in the highest offices of government and industry. While the colloquium participants did not arrive at ready answers to these complex questions, their deliberations should enhance the level of policy analysis.

The broad coverage of the colloquium in both the popular and scientific and technical press attests to the timeliness of the topics that were considered. Such coverage serves to broaden the debate beyond the scientific and technical community to include the public. This is as it should be.

The AAAS reports and colloquia on R&D budgets and policies have been conducted with the guidance of the AAAS Committee on Science, Engineering, and Public Policy, and oversight by the AAAS Board of Directors. Advice has also been provided by representatives of scientific and engineering societies affiliated with AAAS. A group of these affiliates with common interests in R&D budgets and policies has embarked on an ambitious work plan. We are seeking to expand this effort as well as to initiate other cooperative science and public policy activities with the AAAS affiliates.

September
1978

William D. Carey
Executive Officer
AAAS

Agenda for the Colloquium

Tuesday, 20 June

9:30 am **Welcome:** Emilio Q. Daddario, *Chairman of the Board, AAAS*

Conference Overview: Willis H. Shapley, *Consultant to AAAS for the R&D Budget Analysis*

Keynote Address: Frank Press, *Director, Office of Science & Technology Policy, Executive Office of the President*

10:30 am **Federal R&D**

Moderator: J. Thomas Ratchford, *Associate Executive Officer, AAAS*

Speakers: W. Bowman Cutter, *Executive Associate Director for Budget, Office of Management & Budget*

John C. Sawhill, *President, New York University*

Discussion: J. Thomas Ratchford; W. Bowman Cutter; John C. Sawhill; Philip M. Smith, *Assistant Director for Natural Resources & Commercial Services, Office of Science & Technology Policy;* Hugh F. Loweth, *Deputy Associate Director, Science & Energy Technology, Office of Management & Budget; Panel of Inquiry; and Colloquium Participants*

1:00 pm **Lunch**

Presiding: William T. Golden, *Treasurer, AAAS*

Address: The Honorable Russell W. Peterson, *Director, Office of Technology Assessment, and Member, AAAS Board of Directors*

2:30 pm **R&D in Industry**

Moderator: N. Bruce Hannay, *Vice President, Research & Patents, Bell Laboratories*

Speakers: Wesley A. Kuhrt, *Vice President — Technology, United Technologies Corporation*

Edward E. David, Jr., *President, Exxon Research & Engineering Company; President, AAAS; former Presidential Science Adviser*

Discussion: N. Bruce Hannay; Wesley A. Kuhrt; Edward E. David; *Panel of Inquiry; and Colloquium Participants*

5:45 pm **Reception and Dinner**

Presiding: Rodney W. Nichols, *Vice President, The Rockefeller University, and Member, AAAS Committee on Science, Engineering, & Public Policy*

7:15 pm **R&D and International Economic Competition**

Moderator: H. Guyford Stever, *Corporate Director and Consultant; former Presidential Science Adviser*

Speakers: Stan Ruttenberg, *President, Ruttenberg, Friedman, Kilgallon, Gutchess & Associates*

Arthur M. Bueche, *Vice President, Research & Development, General Electric Company*

Discussion: H. Guyford Stever, Stan Ruttenberg, Arthur M. Bueche, *and Colloquium Participants*

Wednesday, 21 June

9:30 am **R&D and the Economy**

Moderator: The Honorable Mike McCormack, *U.S. House of Representatives, and Member, AAAS Board of Directors*

Speakers: Jordan Baruch, *Assistant Secretary for Science & Technology, Department of Commerce*

Robert A. Charpie, *President, Cabot Corporation*

George S. Lockwood, *General Partner, Monterey Abalone Farms*

Discussion: Hon. Mike McCormack, Jordan Baruch, Robert A. Charpie, George S. Lockwood, *Panel of Inquiry, and Colloquium Participants*

12:30 pm **Lunch**

Presiding: William D. Carey, *Executive Officer, AAAS*

Address: The Honorable J. J. Pickle, U.S. House of Representatives, Texas

Concluding Remarks: William D. Carey

PANEL OF INQUIRY

Margery E. Hoppin, *President, National Council of University Research Administrators*

Charles Mosher, *Executive Director, Committee on Science and Technology, U.S. House of Representatives*

Richard S. Landry, *Administrative Director, Economic Policy Division, U.S. Chamber of Commerce*

Markley Roberts, *Economist, AFL-CIO Research Department*

Benjamin S. P. Shen, *Reese Flower Professor, Chairman of Astronomy, Chairman of Science Public Policy, The University of Pennsylvania (Federal R&D only)*

Robert L. Stern, *Director, Business/Government Relations, The Conference Board (R&D in Industry only)*

George C. Eads, *Program Director, Regulatory Policies & Institutions, The Rand Corporation (R&D and the Economy only)*

Thomas A. Bartlett, *President, Association of American Universities (R&D and the Economy only)*

The Panel of Inquiry will initiate and guide the discussions in the sessions on "Federal R&D," "R&D in Industry," and "R&D and the Economy."

Welcome

Emilio Q. Daddario
Chairman of the Board
AAAS

I welcome you to the third annual AAAS Colloquium on R&D Policy. This Colloquium gives us another chance to mingle our thoughts about research and development so that we can hopefully better understand the importance to our society of the development of knowledge and the difficulties in applying it to our needs.

When we began this effort at the AAAS we weren't really trying to say what our R&D policy ought to be, although there is obviously no lack of opinion about that, but rather to promote discussion on the subject. It was our hope that a better understanding would result from the simple process of bringing wise people together so that they could discuss the subject. Although dollars are important, leadership and ideas are what really count. AAAS has been able to convince some of our most thoughtful leaders to come here and present their views, and you can contribute your own ideas during the discussion. That Willis Shapley, who will be our first speaker, has been able to lead us to this point where a cross section of leaders from industry, universities, and government have felt it worthwhile to participate is a tribute to him as well as an indication that it may be worthwhile to continue the process of publishing a AAAS report on R&D budgets and policies and sponsoring an annual colloquium.

If leadership and ideas are important, they need to be as close to the President as possible. When President Nixon wiped out the Office of Science and Technology, many thought that it would be quickly reinstated. Hearings that I had chaired in the Congress over many years had convinced me, at least, that science advice at the very top level of decision-making was here to stay. Not only was maintaining the concept more fragile than I had expected, but reinstating it was even more difficult. We can thank Congressman Olin Teague, Chairman of the House Committee on Science and Technology, for having taken on that task, for getting the legislation through the Congress, and for convincing President Ford to sign it into law.

We are happy that Frank Press has the assignment of leading the office and pleased with the skill that he has shown in playing his role. We are honored that he is able to be here to present the keynote address.

Frank Press is Director of the Office of Science and Technology Policy and President Carter's Science Adviser. Dr. Press and his staff are developing an effective role among the policy-makers in the Executive Office. Of special importance to the conference has been his interest in industrial innovation and science and technology for developing countries. He was instrumental in formulating the Domestic Policy Review on Industrial Innovation that the President announced in May 1978.

Conference Overview

Willis H. Shapley

Consultant, AAAS

My purpose is to take a very few minutes to state concisely what we hope this colloquium will accomplish.

The program you have lays out the agenda of topics and speakers. We have three interrelated topics. This morning, after Dr. Press's opening remarks, we will discuss Federal R&D. This afternoon, the topic will be R&D in Industry. This evening and again tomorrow morning we will be discussing R&D and the Economy, with the discussion after dinner pointed at international aspects and tomorrow's session taking on, after a good night's rest, the full range of this complex topic. The luncheon speakers today and tomorrow will address important matters within the scope of the conference where their experience and points of view will be especially valuable.

The booklet you have been furnished--AAAS Report III--provides background information on each of the topics and identifies issues and questions that deserve attention. There are many more questions than answers in the book. One reason is that the authors didn't know the answers. Apart from that, in these complex topics one of the real needs is to sort out the questions themselves in a systematic way. This is what we tried to do in the book so that discussions like those we will have at this colloquium may be able to go beyond the endless identification of further questions, further complexities, and further frustrations and get down to the business of considering actual answers, alternatives, and actions. This is what we hope will happen here today and tomorrow.

On the first of our interrelated topics, Federal R&D, there are always many issues. Five issues of general R&D policy are identified on pages 19-21 of the book and I'm sure each of you also has his and her own list. The Administration set a policy course for federal R&D in the FY 1979 budget; Congress is in the process of responding to it. The basic question we want to get at in our discussions is what significant changes should be made in current policies, budget trends, processes, and programs for federal R&D. Are we on the right course? If not, how should it be changed?

If so, what fine tuning is needed and what are the new challenges of the future?

On the second topic, R&D in Industry, the basic question is again: What changes should be made in current policies and trends? Should industry be doing more R&D than it is? If federal and other constraints were removed or mitigated, would industry actually do more R&D? These and many related questions, like those noted on pages 76 and 77 and recapitulated in the final chapter of the book, are what we need to come to grips with.

On the third topic, R&D and the Economy, we should try first to see if there is a consensus on a fundamental question: Can we accept the proposition that changes in current R&D policies or investment levels, in industry or in government will have a positive impact on our future economic well-being? If the answer is yes, then there are the many questions of what changes should be made, how, and by whom. The list of "bottom line" questions in the last chapter of the book provides a checklist that may help keep the discussions on track.

The common focus in each of the three topics is on what should be done. Influential leaders and representatives of government, industry, and universities are here to take part in the discussions and to listen. Today and tomorrow we all have an opportunity to let them know our views and help them arrive at the answers. They in turn have an opportunity to share their problems and perspectives with the rest of us.

Keynote Address

Frank Press
Director
Office of Science &
Technology Policy

This is a most important colloquium on a most important subject. I say this because it is a gathering of people perhaps as knowledgeable about R&D budgeting as any that could be assembled--and almost as influential in dealing with it.

But for all our expertise and interest, we have problems. One reason, of course, is that it is a difficult subject. R&D is not one subject, nor even two, but literally hundreds. And quantifying and discussing them in the aggregate forms that we do, for the sake of budgeting, does not do them justice. It cannot consider all the problems associated with the support of the many disciplines involved. There are so many qualitative aspects and nuances that need to be taken into account. Of course, those formulating and presenting the individual agency budgets try to make the case for these. And during the course of the budget review, my office works very closely with OMB and the agencies to foster a programmatic and holistic approach. But the harsh fact remains that R&D budgeting is still an annual exercise tied to a fiscal cycle, and often economic vicissitudes, that does not conform to the life-cycle needs of creative science or technological developments.

Bearing this in mind, I'd like to use this occasion to raise a number of issues about R&D policy. Many of these are not new. But having personally gone through one complete budget cycle, and being in the midst of another, they are currently very close to me. In addition, and I think more important, they are the kinds of issues we must seriously come to grips with, in the light of what we see taking place in our country and the world today, that is having a profound effect on our economic and social well-being.

There is one overriding issue. To put it bluntly: We need a better definition of, and greater consensus on, our long-term goals for the federal role in R&D. This is an idea we periodically give lip service to in conferences such as this, in congressional hearings, and even in legislation. The latest of this can be found right in Public Law 94-282, which created the OSTP and its many responsibilities.

Title I of this Act, appropriately dealing with National Science, Engineering and Technology Policy and Priorities, finds that "the many large and complex scientific and technological factors which increasingly influence the course of national and international events *require appropriate provision, involving long-range, inclusive planning* as well as more immediate program development . . . ." It also speaks of federal funding for science and technology as representing "*an investment in the future*" and refers to the need for "*policy planning*" and the "*maintenance of a solid base for science and technology* . . . ." All this implies a strong recognition that continuity and long-range thinking and support are essential to the entire enterprise. And this is tied to a better understanding and consensus on the long-term goals when it comes to the federal role in R&D. A clearer definition of such goals, a broader understanding of, and agreement on, what we as a nation want to accomplish, and what longer-term commitment we are willing to make toward that end, is essential. This should not be a matter that is rehashed in each budget cycle.

I am not arguing that R&D be disengaged from the federal budget cycle, nor that we freeze ourselves into inflexible plans. But there is clearly a good case now for more rational management of the nation's planning and support of its science and technology in the face of their critical relationship to our future.

Let me spend the next few minutes bringing up some matters that relate to this subject. They are matters that have been on our collective minds for some time and are discussed at length at AAAS conferences. But we are now much closer to the hour when we will have to come to grips with them--and in some cases, are beginning to do so already.

To begin with, let's turn to that broad topic we refer to as "the health of science." Our future thrusts in science and technology, and our commitments to them, are going to be influenced by our assessment of this health. At present, we need a better monitoring of the health of science. In the past, we have relied on anecdotal statements. More recently, we have moved to input-output figures to monitor our progress. The input figures have been largely those related to budget levels. The output has focused more on resulting effects, such as the number of patents granted, journal articles published and so forth. Such indicators have been helpful to a point. But there is agreement that they can be improved. For example, we need more output information and a better analysis of it. What are we getting for our efforts? How are they contributing? Could they be more effective if allocated differently? We need to get behind the traditional array of statistics, and evaluate more factors qualitatively. Not every number--every patent, innovation, publication, research citation, or prize--has the same significance. Nor do all the numbers mean what they used to mean in terms of their economic and social consequences. It is easy to pose these needs, and difficult to translate them to procedures.

The National Science Foundation has been conducting an in-depth analysis of the Science Indicators prepared for the National Science Board. The latest of these were for 1976. NSF is now hard at work preparing better theory, better output indicators and better models for the Science Indicators of 1978. These could improve our ability to evaluate our strengths and weaknesses, and judge where we stand in regard to others.

In making such a judgment, it may be time to recognize that it is not possible, or even necessary, to be first or number one in everything, as long as our overall primacy is not threatened. And it could be that we need something like an S&T strategy to determine what efforts would be most advantageous in a broad sense, in line with our national goals.

Somewhat related to this is the need for a better understanding and consensus on how much is enough--what level of support will bring optimum results to a certain field, when to cut back on, or terminate, an effort, and when to shift support to an alternative or an entirely new approach. This is not easy. Often projects or programs tend to take on a life of their own. They build a constituency and a momentum that is difficult to deal with. But we must exercise certain restraints, as determined by the priorities and goals we set. There is no major formula to the funding problem, certainly nothing as simple as allocating a percentage of the GNP to R&D. The situation is much more complex, and demands continuing reevaluation and flexibility, even as we strive to avoid underfunding, and try to maintain continuity of support in certain fields.

If we need to know how much is enough, and when to support what, we must also come to a clearer understanding of how the burdens and responsibilities for R&D funding should be shared. For example, in the case of the development part of R&D, what is the appropriate role for industry? In certain fields, there is now a difference of opinion over the timing and extent of federal involvement. A somewhat traditional approach has been established in costly, high technology--such as nuclear power--for the federal government to bring the technology well into the demonstration stage, before turning it over to the private sector. Some people feel that, in some fields, and given proper incentives, industry could be brought into the development picture much earlier. If certain risks and uncertainties were reduced, they might do a more effective job in many areas. This is a dilemma that is at the crux of many of our problems today.

The question also arises as to the government's role where it is the principal procurer, as in the case of NASA or DOD. There are a variety of conditions that would benefit from some new thinking about the best ways for the federal government and industry to share R&D responsibilities. Some of these may be forthcoming as a result of the new industrial innovation study recently announced. I will have more to say on that later.

A number of these matters, and others related to them, are raised in "The Bottom Line Questions" that appear in the booklet prepared for this Colloquium. I think you pose several very important questions about the relationship of R&D to the economy, and our R&D requirements. And I have a feeling that many of these questions are going to be the focus of our attention in the coming year. The state of the economy, the concern with productivity, inflation, innovation and international competition, all call for a new hard look at what R&D can and cannot be expected to contribute. We must be especially careful not to think of R&D as a panacea to every economic and social ill. There are a great many problems where the principal solutions will lie with institutional change, education, political leadership and many other factors.

While we search for clarification on these relationships, there are other problems that demand more attention than we have given them in the past. One of these is the issue of manpower. This has always been a difficult problem--trying to regulate the flow of men and women into the various science and engineering fields, to provide opportunity for our trained talent, and to match that talent to the changing needs of government, industry and academia. This is not a typical employment problem. Our young scientists and engineers represent a most valuable national resource in this high technology era. As I have stated on other occasions, there has been some new thinking on approaches to create positions for young researchers in the universities. This is essential, in view of declining opportunity due to the demographic shift. The good news is that industry's hiring of science graduates has picked up. The bad news is that it has dropped for Ph.D.s in some fields. In engineering, we have a different situation, with a serious shortage of engineers developing. There is also a shortage of toxicologists. All this reinforces the idea that, in our future R&D budgeting and in our science and engineering education planning, we have to devote more attention to the matter of the manpower mismatch. Better mechanisms must be developed for anticipating the needs of various fields and directing our talent to them. In view of our free society and market-oriented employment system, we can never solve this problem completely, but we may be able to do a lot better than we have in the past.

If trained people are one component of our R&D effort that require more attention, facilities and equipment are another. Here we face the serious question of what measures we can take to counter obsolescence. There are many factors involved. The success of our research and development have become increasingly tied to the use of larger, more sophisticated facilities. Today's work demands more elaborate equipment, more complex and sensitive instrumentation, and the need to house, maintain and service them properly. This is true in the universities, in government facilities, and in industrial laboratories. At the same time that this dependency is growing, so is the cost of the equipment. It is growing rapidly because one does not simply replace one's scientific equipment, but needs to upgrade it--to go to more productive and sensitive tools and instruments. In addition, inflation has struck science with a vengeance--with the price increases of some equipment taking quantum leaps, as it were.

This is a serious problem. Many new discoveries hinge on the sensitivity and accuracy that new equipment would permit. In some fields, we are operating in more remote and dangerous environments that require more ingenious and reliable tools. Space and the ocean's floor are no place to cut corners in safe and fail-safe systems. Nor should we expect to find inexpensive ways to monitor minute changes in the upper atmosphere to determine possible influences on climate, or to accurately assess changes in the human cell that might reveal the basis of a certain disease.

In some fields, it may be possible to alleviate the problem of expensive new facilities by sharing them. The idea has led NSF to undertake establishing some regional instrumentation facilities around the country. These will enable universities and industries to share the cost of apparatus in areas such as NMR spectroscopy, mass spectroscopy and x-ray diffraction.

Of course, the current state of our industrial technology demands that obsolete facilities be replaced. As you know, international industrial competition is growing and causing considerable concern. We cannot compete, using outdated plants, inferior and outmoded products. And much of our industrial innovation can only be based on new knowledge and ideas coming out of new and advanced industrial labs. If we are going to maintain our technological leadership, improve our productivity and stimulate necessary economic growth, industry must have the incentive to invest in new plants and equipment.

Since, at this point, we are close to the subject, let me take this opportunity to say a few words about the Administration's new review of industrial innovation. This is the study you have been hearing about over the past few weeks. In brief, the story is this: For many months, my office has been examining the problems related to industrial innovation. A parallel effort has been under way in the DOC. Together, we have consulted with a number of people in industry, government, and academia on the matter. We concluded that the situation warranted the President's attention, and we brought the facts before him, recommending that a major Domestic Policy Review be launched. He gave the proposal his enthusiastic endorsement and commissioned a cabinet-level study to be undertaken by a committee drawn from fifteen departments, agencies and offices. The committee will be chaired by the Secretary of Commerce, with day-to-day oversight by Jordan Baruch who, I might add, has wasted no time in getting the study under way. This is the highest level of attention this issue has ever received.

I do not want to dwell on all the aspects of the study. Many of you are already familiar with its general thrust. But it might be worthwhile to indicate the kind of questions the study will address in developing and evaluating policy options for Presidential consideration. It is anticipated that the options will fall into two broad categories. One set will deal with policies for optimizing innovation and industrial R&D. The other will relate to policies responding to international initiatives. In the first category, we will be questioning whether new or revised government policies are needed to produce innovation consistent with national goals? Will it generate the investment, entrepreneurial, informational, technological and other capacities needed to develop and utilize innovations.

Knowing full well that R&D is not the sole consideration in the innovative process, we will be examining others. We will be questioning what the indirect and direct federal roles of participation should be in the innovative process. We will be raising such questions as: Are significant changes needed in current policies and procedures to minimize contradicting impacts and maximize mutual support? And should mechanisms be introduced to assure that proposed legislation, tax policy, and regulations are assessed for their impact on innovation?

The Secretary of the Treasury, Michael Blumenthal, touched on these matters in his important speech to the financial community last month. He stressed the importance of stimulating industrial investment, particularly in high-technology products, where we must maintain our international initiative.

Related to international initiatives, our new study will raise such policy issues as: What can and should the government do in response to foreign initiatives that might cause U.S. industry to fall behind foreign firms in technology and in world market competitiveness? What can and should the government do to foster technological innovation in order to improve and expand the U.S. position in export markets? I am sure that Jordan Baruch will be discussing this with you in more detail during his presentation.

The answers to such questions that result from this study could provide the basis for important new steps the Administration might take to influence the course of industrial innovation, and in turn perhaps the course of economic growth.

We have to consider all this, not only in terms of what we are doing, but how our trading partners and competitors are operating. And this includes not just their industrial systems, but their whole spectrum of R&D activities. In this regard, we take great pride in our system and its accomplishments. And throughout the world, that system is still held in the highest esteem. Our universities, with their outstanding research related to graduate science and engineering education, and our federal support of that relationship and its connection with national laboratories and other government science activities, have all contributed immensely. But our past success should not prevent us from continually re-evaluating our situation, from looking at it in the light of current conditions. At the same time, we need to monitor the systems and experiences of other countries. Perhaps we can learn something useful by a better understanding of what the German, French and Japanese are doing. Each has a different system that is meeting with some success in different ways. The French have a method of providing federal billets for certain scientific personnel in universities, as a means of stimulating key fields. The new Heisenberg program in Germany has created several hundred assistant professorships that are filled by promising young scientists, in response to a lack of opportunities for young scientists. In Japan, we have seen a remarkably successful system of government-industry cooperation and support. I am not advocating that we copy these ideas or methods, but merely that we understand them and perhaps, if we find it advantageous, adapt some element of them to our own special needs.

Returning to our own system, let me say a few words about its infrastructure, and some of the institutional and managerial problems. This is another area about which there is periodically much discussion, but not much change. I am referring to such matters as patent policy, procurement policy, indirect cost and overhead, and increasing overhead due to federal regulation. The way these matters are managed--or not managed--is having its impact on our R&D efforts. Changes in many of them are long overdue, yet such change has been resisted. We have been looking into some of these matters, discussing them with the people who hold different points of view on them, and trying to arrive at some consensus for necessary change. In some cases (such as patent policy), it has been a time-consuming and frustrating exercise. But we are going to persist--and I hope prevail.

While change is necessary in some of our R&D infrastructures, more stability is necessary in certain aspects. I mentioned, toward the beginning of my remarks, the need for a longer-range outlook in R&D policy. We also need some of that outlook applied to internal planning and support of certain disciplines. As you know, there has been a return of interest to the concept of longer-term grants, as one approach to assuring stability to a discipline. In a speech in April, Secretary of HEW, Joseph Califano, spoke of this strategy and of the need in the biomedical field for a multi-year plan that would "serve to level out the annual appropriations' fluctuations that make rational research planning so difficult." Secretary Califano stated: "A multi-year strategy for basic health research, covering at least five years, is, in my judgment, an extraordinarily important goal." And he gave a number of advantages of such an approach to research support.

While he spoke principally to health research, his ideas are applicable to other fields. For example, we know that if we are to attract and hold the best people in any discipline--and expect them to produce their best--we have to provide some continuity and security. And this applies to the technicians and support personnel who, along with the principal investigators, make up our research teams.

Most of my comments concerning research support have focused on the government-university relationship, as this has been and will continue to be the key partnership in advancing our basic research. There is, however, an increasing interest in the industry-university connection. In the past, there have been attempts to strengthen this relationship. One that comes to mind was the NSF-sponsored university-industry workshops on engineering research; ARPA's use of joint university-industry contracts is another example. There have been others. Today, there is a growing recognition that much can be gained from a stronger linkage here. Certainly our industry needs, and could make good use of, much that is coming out of our university research. And, in many ways, the universities could benefit by a better understanding of the problems and needs of industry. The NSF and DOD are pursuing this matter; on their own, industry and universities are also initiating new approaches to cooperative research. And this may be a matter best left to the universities and industry to work out themselves, with the federal government playing only an indirect role. It should also be noted that some states are having notable success in bringing their universities and industry together--and without federal help.

Important to all that I have been discussing this morning is the matter of education and understanding--in the broad sense that the public and its representatives, both in the government and in the many public interest groups today, are our partners in this enterprise. Their understanding and support is essential. In many ways, it has been forthcoming, but the issues are extremely complex. And there is often enough uncertainty involved to cause what seems like endless debate and delay, in the face of problems that call for urgent action.

Another aspect of this is that it is a process of continuing education. A new generation is on the scene. There is a rapid turnover of members in the Congress. We have an Administration, and new decision-makers and leaders in the public and private sectors--many of whom are not fully attuned to the issues. Some of these people are very diligent and perceptive, and get up to speed on matters quickly. Others do not. All this makes the educational process very difficult. Over the years, and in many ways, the AAAS has been most helpful in advancing this educational process. This annual colloquium is just one example. The

Congressional Fellowship is another. I urge you to keep up these good efforts and develop others.

My comments this morning have centered more on the making of R&D policy--the management of issues, rather than the issues themselves. This does not mean that we, in the Administration, have been dealing more with form than substance. In the course of the year, I think OSTP and OMB have been quite successful in coming to grips with specific issues and launching programs to deal with them. We have an Administration statement and commitment to basic research that is unprecedented. Just last week, the President wrote to the chairmen and members of all the congressional committees and subcommittees responsible for appropriations for basic research. He expressed his deep conviction that the full funding of his requests for that research was in the national interest, and he urged that the committees act accordingly. He stated:

> As the Congress considers final funding levels for R&D programs, I want to emphasize that even relatively small reductions in key agencies--such as the National Science Foundation--or in new initiatives and growth planned for the mission agencies--including NASA and the Departments of Agriculture, Energy, and Defense--would defeat our objective. Modest increments of real growth in these programs are necessary if we are to strengthen the Nation's capacity and productivity in critical areas of research.
>
> As the Congress completes its work on the R&D proposals before it, I wish to reiterate my support for the basic research initiative, and to ask again for the support of the Congress in beginning to meet this national need in the 1979 budget.

During the past year, we have initiated new thrusts in such important areas as human nutrition, competitive agricultural research, solar polar mission, mineral policy, climate research, earthquake hazards' reduction, and industrial innovation. We have begun to reestablish connections between the DOD and universities, and we have created a major new Office of Energy Research. The President has approved a new Foundation for International Technological Cooperation--perhaps the newest and most exciting idea that has evolved in recent years in foreign aid.

In the coming year, I think we can look forward to more accomplishments--even in the face of strong challenges and stringent priority-setting. We know that we are entering a new economic climate, one which will be characterized by fiscal conservatism, and by a great deal of scrutiny, accountability and calls fur sacrifice. However, research has been recognized as an important national priority, and so stated on several occasions by the President. There is growing recognition that the shape of the future will be determined largely by the state of our science and technology--how well we nurture them, and how wisely we use the knowledge and power they provide. If we, in the science and technology community, do our job conscientiously, I believe our efforts will receive the full support of the American people.

FEDERAL R&D

Moderator: J. Thomas Ratchford *(Associate Executive Officer, AAAS)*

Speakers: W. Bowman Cutter *(Executive Associate Director for Budget, Office of Management & Budget)*

John C. Sawhill *(President, New York University)*

Panelists: Philip M. Smith *(Assistant Director for Natural Resources & Commercial Services, Office of Science & Technology Policy)*

Hugh F. Loweth *(Deputy Associate Director, Science & Energy Technology, Office of Management & Budget)*

Panel of Inquiry

Margery E. Hoppin *(President, National Council of University Research Administrators)*

Charles Mosher *(Executive Director, Committee on Science & Technology, U.S. House of Representatives)*

Richard S. Landry *(Administrative Director, Economic Policy Division, U.S. Chamber of Commerce)*

Markley Roberts *(Economist, AFL-CIO Research Department)*

Benjamin S. P. Shen *(Reese Flower Professor, Chairman of Astronomy, Chairman of Science Public Policy, The University of Pennsylvania)*

Federal R&D

Topics addressed during the session included:

- *The framework for developing the FY 1980 budget.*
- *Federal support of R&D, particularly basic research, at colleges and universities.*
- *The relationship between basic research and the economy.*
- *The effects of regulation on research and on the exploitation of the knowledge generated through research.*
- *University-industry cooperation in R&D.*

Introduction

J. Thomas Ratchford
Associate Executive Officer
AAAS

As an introduction to the one and one-half days that follow, I should like to explain the new format for this year's colloquium. A retrospective look at last year's meeting showed that the audience wanted the speakers to give more time to discussion of issues that were raised, that is, more answers and less speech making. So we have asked the speakers to be brief, and we have added a new device, namely a panel of inquiry. The panel will serve to initiate and guide the discussions in each session. After the panel "softens up" the speakers for a while, the audience then gets a crack at both the speakers and the panel. The majority of the panel will participate in all three sessions, thus providing continuity from session to session.

To set the stage for the discussion of federal R&D we have a top official from OMB, the principal agency responsible for determining how the government spends its R&D dollars, followed by the president of a major research-oriented university, representing a sector that receives a sizeable portion of federal R&D dollars, especially in basic research.

W. Bowman Cutter is Executive Associate Director for Budget of the Office of Management and Budget. He served as the leader of the budget analysis group in President Carter's transition organization. Prior tc joining the Administration he held positions as Assistant to the President of the Washington Post Company, Executive Director of the Cable Television Information Center, and Special Assistant to the President of Northwest Industries. He has also lectured in economics and public policy at the University of Chicago. He has degrees from Harvard, Oxford, and the Woodrow Wilson School at Princeton.

John Sawhill is President of New York University. In the private sector he has held positions with Commercial Credit Company and McKinsey and Company. His government service includes positions as Administrator of the Federal Energy Administration and Associate Director of the Office of Management and Budget. He is an economist with degrees from Princeton and New York University.

Prepared Presentation

W. Bowman Cutter

Executive Associate Director
for Budget
Office of Management & Budget

I will begin by boasting a little bit about the 1979 budget, but in the process I will raise two concerns. Then I will present a sense of the future, both in terms of how we will manage the budget and what the budget will look like in the next year or so.

Those of you who were here last year will remember that I appeared at almost the same time in the budget cycle as we are now. We have just finished our previews of the FY 1980 budget, and made our last presentation to the President. The guidance for the FY 1980 budget will soon go out to the agencies, and OMB will receive their budgets on the first and fifteenth of September. Then throughout the remainder of the fall, we will go through the more formal and final budget decision process.

At the time that I appeared last year we had been in office three months and the principle concern in the audience was how R&D would fare in the budget given our commitment to a process called zero base budgeting. The essential concern was how a subject such as basic research that was long-term in nature, not urgent by the standard political definitions, and extremely discretionary could survive in a constrained budget that would be developed through a process that is purported to look at things by dividing them into decision units, requiring rankings and trading them against each other. I argued that the process was designed explicitly to take into account the various kinds of concerns that the audience raised at the time. It was an interesting discussion and one from which all of us at OMB benefitted as indicated by the results of the 1979 budget. Let me describe what we did.

First, we looked at the R&D budgets in every R&D agency and divided them into reasonable decision packages. (I hope each year that our definition of what a decision package is will become more meaningful.) The decision packages were ranked by agencies--at times we altered the rankings--and we argued with agency heads and in front of the President about the alternatives that the rankings and the individual decision items posed. For example, I would guess we had three separate meetings with the President on the question of the orbiter program at NASA and whether it should include four or five orbiters.

R&D was examined in detail in the process of our budgeting exercise. Specific emphasis was given to basic research and to agency missions. Our philosophy was that the policy for basic research would be developed deductively and inductively. First we would look at the specific missions of the classical R&D agencies and recommend to the President the appropriate level and direction of basic research that those missions required. Then in order to avoid a policy based simply on this examination of a large number of specific pieces of the budget, we would look at what we had done to the total, both in terms of dollars and direction. If the Executive Office or the agencies were unhappy with the final package, it would be adjusted from the point of view of an overall policy. To the degree that we required an overall adjustment to the basic research total, we raised the NSF budget and shifted its perspective a bit in order finally to come out where we wanted.

The result of this process was twofold. First, there was a decided and explicit tilt towards long range basic research in the federal budget. Second, the role of the federal government in development was deemphasized. The basic research policy was stated explicitly in announcements of the President, including his Medal of Science ceremony, his State of the Union message, and his budget message, and we argued that there were important social and economic reasons for this emphasis despite the fact that it clearly was not the most popular set of budget decisions that we could present to a Congress or the public. To summarize, we looked at basic research in detail as we said we would, we wound up with a favorable policy towards basic research as I had suggested we would, and President Carter enunciated this policy extremely clearly in at least three important messages.

The reception to this general policy has been quite good, particularly from this group. (At OMB we get so few plaudits--not that we seek them--that one of them every now and then is awfully nice to see.) What will emerge from Congress is much less clear, particularly I think because of recent events in California surrounding Proposition 13. All of the appropriation requests are under a funny kind of pressure, and it is much more difficult now then when we published the budget to know precisely how it will come out. But we are maintaining the same set of policy commitments, and we will continue to argue that this policy ought to be embodied in the budget as it finally emerges from Congress' appropriation process. As recently as a week ago, the President wrote letters to the chairmen of the appropriation committees to underline this point.

I would now like to raise very briefly some concerns. The first has to do with the course of basic research and R&D expenditures in private industry. I only quickly skimmed Frank Press' speech, so I do not know whether he treated this topic in detail, but it is one we are concerned about. The evidence and statistics are probably clearer to everyone in the audience than they are to me, but I do know them and I have been spending quite a bit of time, both with the OMB staff and with Frank Press on trying to define precisely what is happening to research and development in American industry and the private sector in general, why it is happening, and what can be done about it. The answers at this point still remain disturbing. What is happening seems to be that we have been in a period of secular decline in expenditures on R&D broadly classified within industry and the private sector in general. It is very difficult to say to you, and it is very difficult for anyone to say, what the exact effects of that will be, except that we believe that the effects cannot be good, and must in the long run be disadvantageous to the economy. I don't know whether this decrease in R&D expenditures is responsible for the surprising decline over the last business cycle--say the last five years--in business investment. I don't know whether the decline in productivity in the U.S. over the last three to four years is a result of earlier changes in R&D spending. But neither of these facts are comforting. And since both of them bear at least logical relationship to the level of R&D in industry, we have to be worried about the long-term trend. I do not have any simple answers for what we can do about it.

What we have done is try as best we can to mount a serious effort to examine the issues. Frank Press probably described the project, so I will only review it briefly. After several long discussions with the private sector, the universities, and scientists, Dr. Press has convinced the President to undertake a look at basic research and innovation to be led by the Commerce Department. This is an extremely important problem, one that may be affecting the direction of the economy. We are only at the beginning stages of wrestling with the problem now, and the AAAS report has served as an important primer and an important introduction to the issues.

My second concern is with the policy in the FY 1979 budget regarding development. As I have said, there was a tilt away from federal expenditures on the D in R&D. The basis for this decision is our feeling about the proper roles of the private sector and the public sector. This issue is intimately related with the direction of basic research and development in industry and the private sector in general.

A problem that we faced throughout last year's budget and that we will face in this year's budget and clearly in coming years' budgets is what should the federal government support beyond basic research. The economic argument for investment in basic research is clear and unassailable; basic research is a public good and the returns from basic research accrue to a far greater spread of the economy and the society than simply to the investor. There is a prima facie case, therefore, that if those investments were left to the private sector, there would be substantial underinvestment. Thus support of basic research is a need the public sector ought to meet. But, I don't know if that is the case in the area of development. The further one gets towards classical, commercial development, the more problems I have, and I think OMB has institutionally, with federal expenditures. There is clearly a grey area in which we begin to leave federal and public investments, which we are quite certain yield a public return, and we begin to enter into investments about which we have many more doubts. Those doubts are based on the fact that while I think the public sector is quite good at funding basic research activities, it is not good at all in carrying through development with the attention to markets that is required. We have at least three concerns about the federal government's role in development.

First, we see a need to avoid replacing the private sector by public sector expenditures. For example, we took a great deal of heat and criticism for the solar budget in the 1979 budget. I would argue that the solar budget was an extremely good budget, one which is difficult to assail if the character of expenditures is examined. We were criticized for cutting direct federal expenditures in one of the classical solar areas, solar heating and cooling. We concluded that the area had long since gone beyond the point where it needed to be underwritten by the federal government; it is near a takeoff point in industry and in the consumer's mind. So we agreed to a tax credit for the use of solar heating which seemed to be the most effective way that the federal government could stimulate commercialization of a technology that seemed well on its way. At the same time we shifted monies into basic research and into more exotic solar technologies. Many did not agree with this approach. However, I would argue that it is important for the federal government to avoid replacing and substituting for the private sector if only because resources are scarce.

Second, the government has a great deal of trouble coming to a decision about what future demands will be. That is not really what we do best in the public sector. My judgment, based not simply on looking at R&D but across the entire budget where we are engaged in many kinds of overlaps and intersections with the private sector, is that the federal government does least well in the area of judging market response and judging risk. We are not trained for this, and institutionally it isn't what we see ourselves as having to do. The case of the solar power satellite illustrates my point. At this time we don't have the slightest idea of the potential delivered price of electricity from that technology as opposed to others or of the feasibility of building it. And yet, we are getting enormous pressure to embark on the power satellite couched in many of the same kinds of terms used in the rationale for support of basic research. To us this area seems to overlap very significantly with the private sector. Not only must there be a much more specific look at price curves and feasibility, but more importantly, there must be someone willing to take on a very substantial measure of risk before the public sector has any sense as to whether it is a feasible or a durable technology over the long pull.

Finally, we see in the area of development and demonstrations a direct conflict between the kinds of investment that are probably most efficient in private industry and those that are most efficient in the public sector. My experience in private industry showed me that competition is a good thing. Companies engaged in parallel market development will maximize the chance that the technology will be developed at the highest quality and the cheapest possible price to maximize the benefits to the consumer. From experience with the public sector I have found this not to be the case in government. We are not good at developing multiple technologies in the public sector. And yet there is always a pressure as we move towards the demonstration end of the R&D spectrum that the federal government should invest in parallel and multiple demonstrations. Coal gasification is a problem that we are currently wrestling with in exactly this manner.

To summarize, we have no problem at this point with federal support of basic research, and we have supported consistently a very positive policy towards basic research. We begin to have very real concerns, however, about what the public sector's response ought to be and what its policy ought to be with respect to demonstrations and development, the D part of R&D.

Now let me conclude by giving you some sense of the future for OMB and the budget. I will talk first about process and second about the fiscal outlook. We have spent a year now with zero-base budgeting and we found that it can be extremely useful, but like any analytic technique it does not make decisions for you. Particularly I found that zero-base budgeting does not change the political terms of trade. The fact that we may come up with a ranking of programs or a brilliant argument why one program is worth something and another program is worth nothing, doesn't mean at all that an audience like this or the Congress will accept that judgment. While I think that we have made a more than marginal improvement in our analytics, I wouldn't pretend for a moment that it makes our decisions for us.

We are looking at two other analytics for the 1980 budget that we think will also improve the way we look at problems. One is in a sense vertical and the other is in a sense horizontal. First, as we announced in the 1979 budget, we are moving toward a multi-year budget. In the future we will be budgeting over a three-year period. Now what does that mean? It means that to as great an extent as possible and where appropriate we will present decisions to the President in a three-year context. We will ask him and the agencies to make the decisions with respect to discretionary programs over the three years, and we will publish those decisions. Thus, in the 1980 budget, the out-year numbers will represent for the first time, not simply a carrying out of existing policy but policy changes in future years where those have been made.

Obviously there are problems with multi-year budgeting, particularly in as complex a setting as surrounds the federal budget; two will plague us forever. First, quite frankly, budgeting for the future limits one's discretion. One of the concerns of the group last year, as I said, was how a non-urgent discretionary piece of the budget, like basic research, could survive a process like zero-base budgeting. One of the ways it can will be by our stating and budgeting for a specific policy like basic research over a period of years. That presents the problem, of course, of limiting our flexibility in future years. We will always be walking a fairly close line between being as explicit as possible because we believe that the multi-year budgeting gives us more control in the long run, but at the same time, trying to guard our discretion in the short run. The second problem we have in enforcing a multi-year budget is that people are always much less serious about future years than they are about the current budget year. Everyone has a high discount rate when it comes to decisions for the future.

The second analytic is a process that we will call cross-agency zero-base budgeting, which will raise a number of research questions this year. There are overlapping programs in the federal government and even if they don't involve a great deal of duplication, the objectives are often parallel. Beginning this year and beginning with a limited number of program areas, we will "rope off" an area and require that activities in the area be ranked across agencies as well as within an agency. Thus, we will choose an area, as for example toxic substances' research and regulation, define the agencies that are most directly involved and the pieces of their budgets that are most directly involved, and ask those agencies to rank all the relevant activities so that we can present to the President a ranking of that problem as well as a ranking within each agency. This is going to be the most difficult thing we do in the next six months because the institutional pressures run against inter-agency comparison of this sort.

Finally, what is the future outlook for fiscal policy? For a variety of reasons, we think the economy requires a significantly more restrained budget in the next year. The FY 1980 budget will be the tightest budget in a decade. Our task is to literally go below what we have currently defined as the base of federal expenditures and hold it that way for the 1980 budget. This will be done across the board; it won't be done by picking out those areas where we think we can get away with the most. Our fiscal problem is too broad to be able to do that. Furthermore, the politics of life are such that only by making a convincing case of the need for general fiscal constraint and applying that across the board, do we think we can sustain the policy. It will be an extremely difficult budget, and we will be asking everybody, including this group, to accept a pause, as yet undefined. We need to accept a pause in the rate of increase in the budget in order to bring about a correction in the economy, which we see heading in some very unfavorable and distasteful directions.

Prepared Presentation

John C. Sawhill

President
New York University

The federal budget for research and development is a matter of great concern to all of us here today--the ramifications of this budget, particularly as universities enter a period of declining enrollment, are paramount to the federal government, the nation's industries, and, ultimately, the general health, welfare, and prosperity of the American people.

The federal research and development budget provides a basic overview to the activities of the nation's scientific, intellectual, and research communities. From the federal viewpoint, it is as you describe in the AAAS Report III, "As a window on the anatomy of science policy, the budget process has no peer."

Generally, university leaders view the FY 1979 budget for research and development with optimism, although it does contain significant areas for concern. Certainly the proposed increases are a welcome sign since nearly seventy-five percent of all basic research carried on in the United States is done within the university system. President Carter has said that the budget increase is an investment which will ultimately contribute to economic progress, national security, and pressing national concerns in such areas as energy, environment, health, and national resources. And, in asking specifically for an increase in the total of research and development funds earmarked for colleges and universities, the President recognizes the historic and important contributions made--and currently taking place--in our academic institutions. We appreciate President Carter's position and his concern for research and development.

However, there is a vast difference between the development of the budget in Washington and the quiet process of discovery in a university research center. Today, I want to bridge this gap so that the budget process here will more accurately reflect the problems which exist in the universities.

As is shown in the AAAS analysis, the proposed budget for FY 1979 includes nearly two percent more for basic and applied research and development in colleges and universities, measured in constant dollars, than did the previous budget. In itself, an overall two percent increase above the affects of inflation would hardly qualify as a major increase. However, of the two percent, the actual funds allocated to development and applied research will remain level; the funds proposed for basic research--and this is significant--will increase by nearly five percent. This policy change recognizes the essential role of basic inquiry, reversing previous administration's attempts to channel research funds into very narrowly focused areas.

We recognize the difficulty of these focused research programs in response to national political pressures. All too often, scientists and researchers have had to disguise creative basic research within the context of these types of projects in order to receive support. Today, the Administration's recognition of the value of basic research activities helps to alleviate a growing "grantsmanship" mentality among scientists and creates a healthier atmosphere for the future relationship and cooperation between science and government.

To reinforce this atmosphere of partnership, we are pleased with the President's appointment of a distinguished university scientist, Frank Press, as Director of the Office of Science and Technology Policy, and the decision to retain this office within the White House structure. This decision will help create a better understanding and environment for basic research within the Administration. Also, the President specifically praised science and technology in his State of the Union message, and set as a national priority the need to improve opportunities for young scientists and engineers, as well as the need to replace obsolescent scientific equipment. In singling out these needs--the difficulties of young scientists, and the limitations of outdated research equipment--the President recognizes that these are problems not only for universities but also for the nation and the well-being of her people.

Nevertheless, there are a number of issues and concerns that university leaders must raise in relationship to the proposed budget. First is the amount for basic research--a critical issue. According to the President's budget message, the Administration believes that--and I quote--"appropriate basic research opportunities" justify "a real rate of growth of almost five percent for basic research in 1979." Certainly, it is dubious that this amount can both improve equipment and provide significant funds for basic research.

A real rise of five percent, or perhaps a bit less, for basic research in higher education could easily be absorbed in the acquisition of up-to-date equipment alone, leaving little or nothing for an increase in the manhours devoted to basic research, or for assuring that younger scientists receive a share of funds that would make maximum use of their talents. The fact is that after several years of stringent budgets, universities must now upgrade research equipment. And, let us be clear in this message--I am not referring to buildings or classrooms. Discovery today may still be a lonely process, even for a team of researchers, but if a breakthrough is to occur, it requires state-of-the-art equipment. You cannot cure today's ills with laboratory equipment built for yesterday's problems.

According to studies by the National Science Board,[1] and I quote, "the proportion of NIH research project grant funds allocated for permanent laboratory equipment has declined from 11.7 percent in fiscal year 1966 to 5.7 percent in 1974." The same trend is true in the other funding agencies and the decline continued up until the present administration. This situation is exacerbated by the spiraling cost of equipment and the increasingly sophisticated equipment necessary to carry out research.

If a large share of the five percent increase is to be absorbed by deferred equipment needs, the amount left to fund new basic research projects will be minimal. The potential accomplishments of research will, therefore, not reap the harvest intended in this budget, and I fear may set a trend for a future downward reappraisal of the capability of university research in the coming decade.

I applaud the President's extraordinary stress on "economic well-being" and "the continued vitality of our economy." But if this reasoning is the primary justification for increased federal spending on research and development, it presents certain pressures for the justification of basic research. It is difficult, possibly impossible, to apply the zero-based budgeting approach to the uncertainties of basic research. This strain exists even when the government thinks of itself as buying basic discoveries.

In the words of the AAAS analysis, "the linkage between basic research and its ultimate impact on the economy is long and loose." It is incumbent on the scientific community to explain how this linkage works, and how, without this basic research, American industry would lose its competitive edge. While university people do not want to justify the value of research and development exclusively on economic benefits, we must begin to develop a better understanding of these "long and loose linkages." Such analyses would be useful, especially to those for whom the economic argument is paramount. But we must also be certain that it is fully understood that the road from discovery to application is a long one--yet, one well worth the investment.

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[1] Smith and Karlesky, The State of Academic Science, Vol. 1, Change Magazine Press, 1977, p. 169.

We must fully understand the nature of the research process. I believe that a careful study of this subject by historians of science and technology, economists, and specialists in technological assessment could yield valuable information to clearly justify basic research in economic terms. As compared with research and development itself, this kind of analysis would cost very little and might help to establish a more secure basis for research and development--one far more comprehensible to politicians and those responsible for budget management.

Beyond the concern for the size of the budget and justifying the importance of basic research, is the recognition that universities and private industries must work more closely together. The President's science adviser and other high officials have asked whether the United States might be falling seriously behind other nations in technology applied to industrial uses. In response, they are urging government support of the private sector. Some university officials are alarmed at this approach, but I welcome it. American industry must compete effectively in the world market. Encouraging industry to maintain a technological edge will generate new forms of cooperative efforts between the university and the private sector.

Universities should welcome this challenge and ask what role they can properly assume in this effort. One way to work together is to encourage consortial arrangements between industry and higher education in working on research and development in the neglected middle ground between basic inquiry and product applications. The AAAS analysis calls this "a policy no-man's land." I would call it an enormous opportunity, both for university scientists and for American industry. What is needed here are social inventions and seed money. The "social inventions" we need are new forms and techniques to develop more fully the legal and economic relationships that would facilitate a fruitful settlement of this "no-man's land." In this regard, the federal government will probably be able to help as much by establishing a structure as by allocating funds. Clearly, there would be issues about patent rights, proprietary information, and research freedoms, but the problems would yield to organization ingenuity _if_ the incentives existed.

Cooperative applied research between industry and the university could also serve to involve other experts who are not themselves scientists to solve the challenges of applied research. At New York University, for example, we called together a distinguished group of faculty to consider effective energy utilization and found not only research scientists who wished to take part, but also a large number of faculty with related approaches in business, economics, and public administration. With seed money and the proper organizational and legal forms, a group such as this could develop many productive relationships with industry, as well as with government.

Even within the universities it is important to encourage interdisciplinary forms of research and application. We have tried to accomplish this at New York University by setting aside incentive funds in order to challenge our science faculty to develop such new projects. This Research Challenge Fund encourages innovative, interdisciplinary research. Among the innovative projects now being developed is a prototype of a new urban wind energy conversion and a joint project between chemistry and medicine to develop a localized mini-environment for burn and orthopedic usage.

These interdisciplinary factors are best perceived by administrators who know a particular institution closely and who are willing to allocate funds by using an internal peer review system. Our fund at New York University is enriched by the existing Biomedical Research Support Fund from NIH. Unfortunately, at NSF comparable funds which could have well-served the physical and social sciences were cut from the research and development budget, because the Administration felt that such programs constitute a "college aid program" and depart from the criterion of scientific merit as determined through peer review. As our Challenge Grant Program suggests, however, an internal system of funding can help to generate important projects in applied research and at the same time can still meet peer review standards.

I agree strongly with the Administration's goal of allocating funds by merit, but argue with various kinds of merit that need to be rewarded. Paralleling the dominant, time-tested method of national decisions based on peer review within specialties, the Administration ought to consider a system of decentralized grant-making, based on review by institutional peers. This would involve small starter grants in a block-form giving greater flexibility to the universities.

Also, I would call for a new program of aid to academic institutions, alongside the major system of federal grants directly to individual scientists. I urge that a system of federal research challenge grants be considered for inclusion in the FY 1980 budget. Such a program could offer special benefits in the complicated fields stressed by the President, fields such as energy, health care, and the environment--all of which call for new combinations of scientific and nonscientific talent and are especially important in forging relations between the academy and industry.

In closing, I feel it is important to keep our industry competitive, while at the same time coming to grips with problems which universities can help solve, including effective energy conservation, urban problems, as well as the more apparent projects in medical research and other areas long associated with university research. Universities must succeed in this role, even though the years ahead are going to be particularly difficult. Universities are facing declining enrollments and, with ever increasing costs, it is clear that tuition income will not even minimally support the time of faculty members engaged in basic research. And, I question whether tuition funds should ever have been used to support basic research. A decline in the number of students served in the coming decade, however, should bear no relation to the benefits our society can derive from research done by university scientists and scholars. Indeed, the societal problems in the years ahead will continue to grow--now, more than ever before, we must invest heavily in both basic and applied research. Clearly, additional federal funding must be found to continue these efforts if America is going to remain in its leadership position.

We are increasingly aware of a large number of technological problems existing in the world today--problems which must be solved; there are simply no other choices. But, in this country, we have not yet fully grasped the unique contribution that university talent can make to their solution. The form of this contribution remains to be developed, as much by the universities as by the federal government. As this form becomes clearer--and time is working against us--I am certain that it will include closer cooperation among fields that bear on policy analysis, and between universities and the economic sphere. Such cooperation will provide exciting and innovative solutions.

I welcome the Administration's understanding that research and development are better approached not as a product one buys off the shelf, but as a sober and yet exciting long-range investment, and I call on the House and Senate to respond with significantly expanded levels of support for research and development in the years ahead.

Discussion

Charles Mosher began the discussion of federal R&D with a question to the representatives of the Executive Branch: "Does the Executive Branch perceive the new congressional budget process as becoming dominant, diminishing the influence of the Executive budget?"

In response, Bowman Cutter outlined the developments which had taken place since passage of the landmark Budget Impoundment Act of 1974. The Act set up two new major budget committees, one each in the House and the Senate, and established a procedure under which Congress would carry out its budgeting. The development of two joint resolutions are required under this procedure, one in May and one in September of each year. The first one embodies a sense of the Congress as to tentatively what its fiscal goals are. It establishes a ceiling for outlays, a floor for receipts (therefore a deficit), and tentative totals for each functional area. In September the second concurrent resolution, in a sense, sums up all of the actions taken in the separate appropriation committees and again requires a vote by the Congress on the totals. To the degree that actions by the appropriation committees are inconsistent with this resolution, there has to be a reconciliation motion and another concurrent resolution.

Theoretically, the Act involves a significant restraint on the Executive by forbidding impoundments--the Executive decision not to spend monies which had been appropriated. A fairly complex procedure now divides such expenditures into deferrals (decisions to spend later in a given fiscal year) and rescission (decisions not to spend in a given fiscal year at all). In the case of the first, the Executive must send the Congress a deferral notice; Congress must vote not to allow it. In the case of the second, the Executive must send a rescission notice and Congress must vote to allow it before the rescission can be put into effect.

The Act provides an extremely effective mechanism by which Congress can look at budget totals, thus leading to a considerable improvement in the making of fiscal and general economic policy. In the process, however, the Act has created a long-standing institutional quarrel within the Congress regarding the respective roles played by its appropriations, authorizing, and budget committees.

While there is a clear sense that under this new budget process the Congress is much more assertive in the area of program development and specific program trade-offs, the institutional structure of the Congress still involves a complex process for decision-making. In the end, the hierarchical structure of the Executive with a President who makes decisions must be the dominant influence on the overall decision-making process of the budget.

Hugh Loweth added a concern about the degree to which Congress is becoming involved in budget details in R&D programs, for example, the examination of projects in the Department of Energy on a line item basis. The committee jurisdictional disputes also add to the problem--too much detail, too much confusion, too much work, and not enough opportunity to get on top of the problem. Philip Smith concurred that this year's congressional appropriations' process was a reflection of the overall budget act. It will take time to work out and fine tune this new process. An opportunity exists here for the two committees of Congress concerned with science and technology to try to provide an overview function as is possible within the Executive Branch regarding R&D, and to try to gain a picture of how the overall research and development activities fit together.

A major concern of the universities as expressed earlier by Frank Press and John Sawhill is the replacement of obsolescent equipment. Emphasizing this, Margery Hoppin directed her remarks to the OMB representatives. As a recent Science editorial pointed out, industries are the only ones who can easily afford to upgrade their scientific equipment. Without access to the highly sophisticated instruments that are being developed, the universities will be placed far behind in their quest for answers. She expressed the hope that the funding agencies would be more articulate with the Congress during the budgetary process regarding their specific needs and not merely request an increase in the budget for basic research. Cutter agreed that OMB would certainly try to be more persuasive and more specific with the Congress.

A more complex part of the issue involved the "A-21" problem (regulations which define university overhead charges for research grants). On the one hand, the universities feel the regulation procedures inhibit rapid acquisition of state-of-the-art equipment by prohibiting interest charges on grants and contracts and also prohibiting "use" charges on federally purchased equipment for replacement cost resources. On the other hand, the Congress has indicated that OMB should develop consistent and clear accounting principles for grants to universities which will not alter the nature or effectiveness of the character of the research enterprise. At the present time, this difficult situation has not been resolved, and ultimately may not be resolved to the satisfaction of all concerned. However, OMB has announced a delay in the publication of the rules in order to further consider the problem.

Cutter spoke of a restrained budget facing us for some years to come. The Carter Administration will ask everyone, including the R&D community, to accept a pause--"as yet undefined"--in the expected rate of increase in the budget in order to make corrections in the economy. Markley Roberts questioned whether the Administration's concern for budget restraint, justified as it may be in political terms, is consistent with the kind of healthy, full-employment economic growth that provides incentives and resources to support research and development. The American workers and their unions basically support scientific and technological progress achieved through R&D, and consider full employment the key to this progress.

Cutter retorted, "We're not moving toward a restrained budget for the hell of it. We're doing it because . . . we see the economy in an extremely ticklish point. Productivity seems to have fallen off on a cyclical basis within the last year or so, inflation is up much above our guesses, and we are now in the fortieth month of a recovery with a deficit somewhere in excess of $50 billion." He warned that if federal budget planners don't tighten their purse strings voluntarily, other actors with clear powers in this area, for example the Federal Reserve Board, will move "much harder and with much more blunt instruments than we have." The choice of a moderately restricted fiscal policy is seen as "the best among the real possibilities that we have."

In examining this rationale, Sawhill pointed out, first, that the size of the federal budget deficit is somewhat counter-balanced by the size of state budget surpluses, plus the trade deficit. "If you look at the total impact of these three on the economy, the federal deficit really is not having that large an inflationary impact." Secondly, one of the ways to improve productivity, and at least in the longer range to bring inflation under control, is by maintaining an increasing investment in research and development. Sawhill hoped "the brakes aren't put on excessively in the R&D area, because this is a potentially high payoff area for bringing inflation under control."

The decline in basic research in industry is disturbing to the Administration. "Because of the long payoff period for basic research, could a very likely reason for this decline have been a worsening environment for long-term investment projects in American industry?" questioned Richard Landry.

One major factor to consider stated Cutter, "is the enormous growth in the governmental sector in the last ten years . . . in the undefinable area of detailed intrusions into operations." The level of regulation has increased enormously. In ten years we have moved from a series of classical regulatory agencies, which basically did economic regulation, entry into markets, price setting, and so on, to regulation to accomplish specific purposes. In order to accomplish those purposes, we have dealt in detail with the operations of major social institutions, such as businesses and non-profit institutions. "An unintended effect, which is not a criticism of such regulation," specified Cutter, "is that it is generally more difficult to do things in the private sector than it was some years ago." He doubted that anyone could seriously maintain there is a dearth of opportunity for investment. However, since investment could be defined as long-term payoff, the inflationary economy of the past ten years has made the investment managers more than a little bit chary about the kinds of investments they make.

A participant, citing Cutter's views on investment, pointed out that the two main parameters to look for in any investment, whether it is R&D or capital investment, are the risk and the reward. He suggested that in our current environment there are two principals which inhibit that kind of calculation, whether it is done with the middle of the abdomen or between the ears. One is an unpredictability in the degree of government control in the future. The other is a prediction, not only by the government but by large elements of our society, that things are going to get a lot worse before they get better. As a consequence we have to think in terms of conservation; we have to think in terms of a regulated and smaller gross national product. Anytime there is a slowing down of the economy, or a recession mentality, the reaction is to forestall investment, stay liquid, and keep all options open. Investors are reluctant to make commitments because they are really not sure of the future. As soon as the economy starts to turn around and growth seems possible (much of which is subjective in the minds of the people who both run and exist in the country), people are willing and ready to take even larger risks for those presumed larger rewards. While they are not sure how it is going to be in the future, they do feel it is going to be better.

Some participants believed that two of our great problems today, both in R&D spending and in capital spending, are the feeling of pessimism together with the growing and increasing intrusion of government into our decision-making ability.

Benjamin Shen called attention to the little-publicized fact that, due to the expected job scarcity, the size of the applicant pool of incoming graduate students in physics, chemistry, and math has dropped drastically nationwide since about 1972, in some fields by a factor of two. The drop leveled off recently, but the pool remains at the lowered level. As a result, the nation may begin to face a serious lowering of the quality of basic research in these critical areas in five to ten years. Reliable statistics on the drop in applicants are hard to come by, because universities don't like to advertise it. And it is not reflected in the usual graduate admissions and enrollment data perhaps because there is a widespread tendency to dip deeper into the pool for less qualified applicants. Asking about the government's interest in this problem, Shen added that the dwindling applicant pool might lead to a future depression of first-rate basic research to a level that could adversely affect not just economic benefits but even national preparedness.

"This is very much a problem of concern for which we don't have the answers," replied Cutter. OMB discussed it with the President as long as eight or nine months ago and has held and will continue to hold a series of discussions with university figures. But the problem is a demographic one. The area of great growth has passed; overall enrollments are down; supporting plants are beginning to decline, all of which, in turn, affects job opportunities. While basic research is not and should not be tied in some permanent sense to the level of enrollment of universities, it has evolved that way in our society. In the past, it was convenient and good to do it that way. As a result, we are going to have to develop some quite new institutional arrangements as clear demographic patterns begin to emerge.

Footnoting his earlier remarks, Sawhill stressed the need for closer cooperation in basic research between industries and the universities. He urged the Administration to think about a program which would not only provide incentive funds, but more importantly, would force them to get together and work out these new institutional arrangements. Under this sort of consortial arrangement between industry and the universities, what are the benefits of institutional versus individual ties? Sawhill theorized there would be a longer-term, closer working relationship; it would involve industry and university people who might not normally be involved in a science research project; and it might result in increased attention by industry to basic research.

Another participant wished to challenge a mind-set which seemed to be prevalent and which was repeated over and over again--the idea that basic research can only be done in universities. He asserted that there is an imbalance in the support of basic research that primarily goes toward the university and the support that could go to other groups, particularly industry or government in-house laboratories. The support that goes to universities does not create permanent jobs, which is one reason for a decline of good students and for a surplus of basic researchers. He suggested that if support went to industry on the basis simply of excellence, the researcher in industry would be far more effective in promoting the synergistic relationship that will spin off from his research to the industrial activities. The government in-house capabilities are being seriously reduced by effectively driving the best researchers out of government service. It is, for example, much easier for those working at a university to get Department of Defense support for basic research than for those working for the Department of Defense.

Tom Ratchford asked if there were any defenders of the university mind-set. Taking the challenge, Shen said he heartily agreed that industrial and government labs should take on a larger share of the nation's basic research. The problem is how. At present, most basic research is done in universities not just because of the mind-set, but also because universities happen to be the cheapest place to do basic research. Besides charging a lower overhead than industry, universities by tradition assist sponsored basic research by supplying large amounts of unreimbursed faculty research time. Donald Langenberg of the University of Pennsylvania estimated that an institution such as his subsidizes sponsored research to the tune of $10 to $20 million a year in this manner. Whether or not this is a good thing is not at issue here, but this "hidden subsidy" does have its consequences. One is that if all the government funds now going to university basic research were to go to industry, only a fraction of the present research output would result.

Another consequence, continued Shen, is that since most universities derive most of their faculty salaries from undergraduate tuition, the health of basic research in this country is tied as much to undergraduate enrollment as it is to government funding. We are already seeing the effect of the expected lagging enrollment on jobs for young scientists. Ultimately, a way may have to be found to decouple basic research from undergraduate enrollment, at least financially. One possibility is for industrial and government labs to take on a larger share of basic research. Whether such a "decoupling" is necessary and how it is to be achieved are among the more difficult issues facing science policy and higher education.

Some discussants felt that economic and regulatory uncertainties were discouraging private industry investment in basic research or long-term research ventures. The federal government is questioning its role in funding technological development. According to Cutter, there is a point at which the government ought not to be involved and cannot do the task as well as the private sector. But there is a degree--although it is a grey area as the AAAS report suggests--to which the federal government can encourage technological development without substituting for private industry.

A participant raised the issue of conformance with agency regulations as a prime cause for reduction or diversion of industrial research funds. In speaking for the U.S. Chamber of Commerce, Landry re-emphasized the changed environment for business, particularly the increasing amount of government intrusion into the private sector decision-making. EPA, OSHA, and several others of the new agencies, specifically, are burdening the business community with regulatory uncertainties and considerably higher and unknown costs. A member of the audience remarked that in the small business industry (specifically the medical products industry) unnecessary regulations may cause opportunities to be lost because of the cost of bringing new products to market.

Smith indicated that in the Executive Office's examination of innovation, quite a lot of time will be spent on the issue of regulation and its varying effects throughout industry. Possibly, underinvestment by industry in new products, longer-term research, and even mid-term research are factors causing instability in the present economic climate. There appears to be shifts of emphasis toward incremental product improvement rather than new product development. We need to understand the patterns in large and small businesses, the pattern in high technology areas, as well as areas where there are more fundamental goods and services that are not high technology in character.

In the same vein, Smith was asked if the Tax Reform Act of 1969 decreases the ability to raise capital for small business development. He did not wish to comment specifically on the Act, but stated that "getting a coupling between the interests in OSTP, OMB, and CEA in the Executive Office and agencies such as the Department of Justice and the Department of Treasury in issues like research and development is something that has not occurred very often in my experience in Washington in public service." There appears to be greater cooperation among the different players in the Washington scene, as well as a high degree of commitment on the part of the people who sometimes have not been so interested in R&D. There is enthusiasm for this industrial innovation examination; and there is a high degree of interest in the Congress. Hence, there may be an opportunity to arrive at some appropriate and measured changes that might aid in the innovation process.

Asked about the intent of the Federal Grant and Cooperative Agreement Act of 1977, Smith briefly explained the Act. Congress has reviewed the mechanisms for federal-private institutional relationships over a period of ten or more years. Some examples of these relationships are the grant as it is used by NIH or NSF, and the contract which has been the procurement mode of DOD or NASA, which are buying goods and services to serve a mission. An in-between area exists, however, where the flexibility of a grant is needed, but perhaps also some additional constraint along the lines of a contract. Using a cooperative agreement in these cases would provide agencies a new tool to use in working out their institutional relationships.

In summary, Ratchford said a common thread throughout the morning discussion had been the effect of regulation on research and on the exploitation of the knowledge generated through research. He asked if there were any additional comments with regard to the future regulatory climate and the possible long-term effects of governmental regulation on the quality, quantity and utilization of research.

Smith wished to dispel any pessimistic notes on the effects of regulation on American competitiveness. He stated that foreign perception may be based on a lack of understanding of the social process in the United States. Other countries may not fully understand our interplay between the private sector and the fulfillment of desired social advances. While at the moment there may be some international loss of American competitiveness, it may not be a long-term decline, merely a retooling. Perhaps by the 1990s we may be ahead of many other nations because of having gone through this process of matching private sector and societal goals.

A participant echoed Smith's views on the effects of regulation on society. Unquestionably regulations to preserve the environment, to alleviate problems of safety and health and other social ills, although necessary and essential, are costly. For example, if you have to put more stack scrubbers on factories, there is an associated cost which shows up in your statistics. The productivity of the individual worker is reduced, or the productivity of the capital invested in the plant is reduced. That is all to be expected. On the other hand, we act and think economically as though we have a certain budget for capital and human energy. If we don't spend it in certain ways, specifically if we don't promote growth and productivity, we won't have any resources left. Our experience during war time seems to repudiate this, because some of the greatest technological advances in this country, and indeed, in many countries, have been made during periods of great stress.

The last word of the morning came from a member of the audience who stressed the necessity for the federal government to try to establish more predictability in the regulatory outlook as well as the economic outlook. There is a definite need to examine the rationale behind agency policies and regulations, sector by sector, and to determine their impact on industry. There was general agreement that the problem is not the existence of regulations, but the uncertainty of the regulatory system.

Luncheon Address

Russell W. Peterson

Director, Office of
Technology Assessment

This colloquium provides a forum for constructive discussion of current issues in federal and industry R&D and the impact of R&D on the economy. I will address the question of how technological goals are set and met in our society and discuss the need to relate R&D to societal objectives of which a healthy economy is only one.

Budgets set priorities. Although the priority setting process in developing the federal budget is completely separate from that of private industry, there are important interactions between these two processes. It is the mutual influences of public and private priorities, rather than one set of priorities or the other acting independently, that often shape the course of technological change.

In considering the influence of federal policies on industry priorities, we must consider more than just the R&D priorities in the federal budget. There are many federal policies--tax policy, regulatory policy, social policy--that influence the setting of technological goals by private industry. How these federal policies interact with market and financial considerations to affect industrial decisionmaking on technological innovation is a complex matter. Yet it is precisely these interactions that we must try to understand if we are to insure that technological change follows a course consistent with social priorities.

We need to give much greater attention to national strategies for using science and technology to reach societal objectives. Let me explain what I mean. R&D is a means to an end. In industry, this point is very clearly recognized. There, R&D budgeting is part of implementing a corporate plan or strategy for getting the firm to where it wants to be at some time in the future. I feel that we also need strategies for using science and technology in order to get the Nation to where it wants to be some time in the future. National strategies would clearly have a very different character than corporate strategies. Except in the areas of defense and space, there is no centralized control.

Nonetheless, the essential elements of strategy are just as pertinent at the national level as at the corporate level, namely: What are our goals, and what are the most effective means for reaching those goals?

I would like to begin by saying a few words about technology assessment as it relates to these questions of strategy. Then I would like to illustrate the need for strategies through the use of two examples--one drawn from the health area and the other from energy.

National strategies for using science and technology may suggest major mobilization efforts like the Manhattan and Apollo projects. These efforts very effectively drew upon the full range of the Nation's scientific and technical resources--private industry, universities, and government laboratories. When needed, whole new institutions were created. These examples were clearly impressively well planned strategies for using science and technology to meet national objectives.

However successful, these examples provide a poor model for what I want to talk about today. In the military and space areas, where the federal government spends over sixty percent of its total R&D funds, there is centralized federal control. One management defines the goal, manages the R&D, and buys the product almost regardless of its price. Although DOD and NASA draw upon the creative resources of the private sector, they remain in absolute control as buyers of R&D. This type of development is clearly outside our free enterprise system.

What I want to consider in this talk are strategies for using science and technology to reach objectives in areas like energy, health, transportation, and waste management. In each of these areas, there is a federal role, but not federal control. The policies of the federal government influence the incentives for the private sector to innovate, but the final decisions on the production, delivery and use of goods and services still rest largely in the private sector.

This makes the development of strategies far more complex. Orchestrating the Nation's scientific and technical resources to achieve these kinds of national objectives poses a challenging task. Nonetheless, it is precisely that task that I wish to address here.

There is a close relationship between these questions of strategy and technology assessment. In a pluralistic and democratic society such as ours, the effective use of science and technology to reach societal objectives depends in large measure on the visibility and integrity of the decision processes by which technological goals are set and met. The basic function of technology assessment is to aid decision-making, and an integral part of technology assessment is the open involvement of a diverse range of stakeholders. Thus, technology assessment is a process that helps to build understanding and agreement on what to do and how to do it. This is clearly pertinent to the task of developing strategies for using science and technology to reach societal objectives.

For the purposes of my talk today, I am going to approach technology assessment from the perspective of problems--not technologies. From that perspective, the role of technology assessment is to assess the relative merits of alternative technologies or alternative policy measures for solving the problem. It is important to emphasize, however, that in view of the many uncertainties involved in R&D, the optimum strategy might well involve the deliberate choice of several routes toward solving the problem. Thus, it puts technology assessment into a problem-solving mode, as well as a mode of anticipating secondary impacts. It considers the forces and incentives driving the development of a technology, as well as the consequences of deploying and using a technology.

This conception of technology assessment is virtually the same as that of strategies for using science and technology. The goal is to solve the defined problem in a manner consistent with relevant public policy objectives. The means include both technological means and policy means.

I have dwelled on this point at some length because the topic I am discussing goes to the very heart of OTA's mission. Thus, it is a matter to which we at OTA are giving serious attention. Yet it is also a very difficult problem that poses a real challenge.

The range of important problems that OTA might analyze far exceeds its resources. Since this is a symposium on R&D budgeting and priority setting, I might take a minute to indicate just how we plan to set our own priorities at OTA. Until now, we have worked mainly on topics requested by congressional committees. We will, of course, continue to be responsive to such requests as are appropriate. However, the Congress set up OTA to take a comprehensive look at longer-term issues as well as those already on the congressional agenda. To fulfill that function, we are now in the process of forming our own priority list of projects to work on.

This will be a list of from fifteen to thirty problems ranked in order of priority. Each year, we will work on as many as funds appropriated permit. The priority list will be a dynamic thing, periodically being reordered on the basis of new knowledge and events. We welcome your inputs to the development of this list.

Let me digress here to comment on the importance of OTA's assignment to help bring a longer-term and more holistic perspective to decision-making in the federal government.

The need to face up to long-term and worldwide consideration is critical. Yet most of our decision-makers continue to focus on the near term and from a local or national perspective.

Henry Kissinger has said that the most critical problem in government is that the urgent steals all the time from the important. This is true in non-government circles as well.

While the rate of change and the interdependence of people everywhere continues to grow, the trends appear to be toward an ever shorter and narrower focus. The AAAS Report on Research and Development prepared for this colloquium points out that in recent years in industry "there has been a significant general shift away from R&D directed at long-term objectives and new products and toward R&D directed at short-term market objectives and the improvement of existing products."

The move by the President in his FY 1979 budget to include more funds for basic research is encouraging but the words used tying such research to economic benefits are disturbing. Unless we continue to support substantial basic research with no other objective than the uninhibited search for knowledge, we will erode the very foundation of technological progress.

At the last Medal of Science Ceremony, the President highlighted a basic problem when he pointed out that in the zero-based budgeting process "many agency heads had relegated R&D to a fairly low position of priority." This is not surprising in view of the fact that the average time the policy-making echelons in the Executive Branch--most of whom have little R&D experience--are on the job is less than two years. This is hardly enough time to nurture the long-term perspective required for the efficient management of R&D.

It appears to me that universities still provide the best environment by far for the long-term focus and pluralistic approach so essential to basic research as long as they can avoid being captured by myopic custodians of the purse strings. Now let me get back to the OTA priority list.

For any problem likely to appear on that list, the question of strategies for using science and technology must be raised. There is no generic, all-encompassing way of doing this. Yet in each case, attention must be given to clearly defining the goals and considering the effective means for reaching those goals.

With this background on what we are reaching for at OTA, let me try to portray for you through two examples the need for giving greater attention to national strategies for using science and technology to reach societal objectives.

I will choose health as my first example. The federal presence in the health sector is large and growing. The federal government currently funds more than two-thirds of all health research in the country, with federal outlays for health research in FY 1979 projected to equal $3.8 billion ($3 billion for Health, Education, and Welfare, and most of the remainder for the Department of Defense and the Veterans Administration).

However, the influence of the federal government in the health sector extends far beyond research. The government now contributes almost one-third of all health spending in the country. Federal expenditures for Medicare and Medicaid provide medical care to the elderly and the needy--many of whom could not otherwise afford medical care. However, rapid inflation in the cost of medical services has also been a major factor in increasing federal expenditures. Increasingly sophisticated and expensive medical technologies are an important contributor to this inflation in the cost of medical services.

The percentage of the G.N.P. spent on health has almost doubled in the last twenty-five years, going from 4.6 percent in 1950 to 8.8 percent in 1977. Annual per capita expenditures have increased nearly ten-fold over this same period--going from $78 to $730. Thus, there is ample motivation for asking: What is our national strategy for using science and technology in the health area? It is clear that our health policies are geared more towards curative than preventive medicine. They lay great stress on insuring that once illness strikes, people have access to adequate health care. They lay much less stress on keeping people healthy in the first place.

This orientation is, of course, a consequence of fundamental policy decisions by the Congress. The point I wish to make here is that this orientation in our health policies has a major influence on the course that medical technology follows, albeit a largely unintended influence. Payment for sophisticated diagnoses and treatment, but not for prevention and rehabilitation, encourages resources to flow in the direction of payment--regardless of the marginal effects on health.

For example, Medicare would reimburse you for the treatment of your pneumonia, but it would not reimburse you for innoculation with pneumococcal vaccine. This type of orientation clearly affects the incentives of the private sector regarding innovation in medical technologies.

Even federally supported health research has generally been aimed at curative rather than preventive medicine. For example, although over forty percent of all cancers are thought to be diet-linked, the National Cancer Institute devotes only a fraction of one percent of its budget to investigating the linkages between diet and cancer. The private sector has had little or no incentive to engage in research on nutrition other than for specific product developments, such as infant formulas or vitamin pills. The hard question on the relationship of diet to chronic diseases such as atherosclerosis, diabetes, and cancer have therefore not received sufficient attention from either government or industry.

Yet the economic costs of illness are staggering. A recent study from the Department of Health, Education, and Welfare estimated that in 1972, the total cost of illness was $189 billion: $75 billion for direct costs; $42 billion for morbidity; and $71 billion for mortality. The costs for morbidity and mortality are estimated from lost economic output due to disability and premature death.

I use these numbers with great reluctance, but do so to point out how hard we work to put a dollar sign on our benefits and costs. Imagine emphasizing only the economic costs of mortality and morbidity! Certainly the suffering that accompanies cancer is more costly than the economic output lost from being off the job, especially when there are millions looking for a job. A multimillionaire flat on his back with cancer would give his whole fortune to rid himself of that disease. What is ten more years of a happy, healthy life worth to you? To your loved ones?

We need to work harder at developing means of measuring progress toward our societal objectives. How can we steer our R&D properly when we are flying blindly? We rely too much on one measure of progress--the G.N.P.--which is far from adequate to do the job. It adds in activities whether they add to or subtract from the quality of life, and doesn't measure at all many aspects of quality of life. A million dollars worth of carcinogens weighs as much on the G.N.P. scale as a million dollars worth of antibiotics.

Last year the leaders of the OECD nations met in Europe to discuss the problems and aspirations of their countries. When they finished, they summed it all up with the single resolve to go home to work to raise the G.N.P. by a given percentage.

I don't wish to belittle the importance of increasing the production of goods and services, but I do want to emphasize the necessity of focusing on some more direct parameters of the quality of life if we are to manage our R&D to further human development.

To realize the potential of preventive medicine would clearly require a different strategy for using the Nation's scientific and technical resources in the health area. Many uncertainties remain, however; our scientific understanding of the causes of chronic diseases is still very deficient. The effectiveness of various policy measures aimed at preventing illness is uncertain--especially when those measures are aimed at changing life styles, such as altering our smoking, drinking, and eating habits. Similarly, the ultimate potential of prevention for containing escalating medical costs--a topic of great current interest--is uncertain.

It behooves us, however, to reflect on some of the great success stories in preventive medicine that stemmed from greater understanding resulting from basic research. Take polio. Contrast the huge cost in dollars and suffering, the iron lungs, the treatment baths, the traction devices, the wheel chairs and crutches, the hospital and doctor bills, the pain pills with a few dollars for a polio vaccine. It is of interest to note that the older treatment for polio made a much larger contribution to G.N.P. There is little doubt, however, that prevention of polio made a far greater contribution to happiness.

I hope my first example has illustrated two points. First, our current health policies have a large but unintended influence on the course that medical technology follows. Secondly, without giving explicit attention to the strategies for using the Nation's scientific and technical resources to reach societal objectives, we are unlikely to achieve them.

Let me consider a second example from the area of energy. Although the issues are entirely different, I hope that this example will also illustrate the same two points as the health example--the influence of federal policies on the course of technological change and the need for a strategic approach.

As in health, the federal role is extensive. The federal government regulates the health, safety, and environmental aspects of energy technologies; it regulates the price of oil and natural gas; it owns and leases much of the lands containing energy resources; and it funds over $3 billion per year of energy R&D in a broad range of areas. Yet, it is the private sector that actually produces and delivers energy. Thus, understanding the influence of federal policies on the various components of the energy sector is essential for insuring that the course of technological change is consistent with national objectives.

Because of the sudden manner in which the country became aware of the energy crisis, and the rapid expansion of federal activity in this area, the question of the federal role in relation to the private sector is a controversial one. Thus questions such as, what precisely are we trying to achieve and what are the most effective means of achieving it are fundamental. Only to the extent that we are clear on these questions of strategy, can we hope to reach consensus on the most appropriate federal and non-federal roles..

One of the most comprehensive strategies ever mounted by the federal government to bring about technological change in the civil sector was the effort to introduce civilian nuclear power. It is highly unlikely that nuclear power ever would have been developed if the atomic bomb had not been produced first under the cost-plus war-time economy. Starting with this basic technology and multibillion dollar government nuclear facilities, the federal government mobilized the scientific and technical resources of private industry, national laboratories, and the universities to develop and demonstrate nuclear power; it provided fuel reprocessing facilities; it provided a conducive regulatory environment; and it imposed a legal limit on the damages that could be claimed after a nuclear accident through the Price-Anderson Act. This strategy was successful insofar as it led private investors to put billions of dollars into this technology, which now accounts for twelve percent of the electricity generated in this country.

However, the strategy followed is now widely recognized as seriously flawed. It failed to close the fuel cycle and adequately deal with the problem of nuclear waste disposal. Furthermore, inadequate efforts were made to insure the safety of nuclear power. As a consequence, serious doubts persist about nuclear power. Rather than enjoying wide public confidence, it has become highly controversial.

The lesson I draw from this experience is one to which both proponents and opponents of nuclear power can subscribe. Where potential risks to human health and safety or the natural environment are involved, there is a preeminent federal role in ascertaining the character and magnitude of those risks in order to expeditiously deal with them. It is far easier to honestly confront potential threats to health, safety, and the environment before, rather than after, billions of dollars in public and private investments have been made. Once commitments of that magnitude have been made, the vested interests are difficult to overcome. We then get carried into the future by the momentum of the status quo.

The key point here is one of perspective. We do not tend to view regulation as being in a problem-solving mode. Health, safety, and environmental regulations were not created to help solve the energy crisis, but for other purposes. Yet from a national perspective, which attempts to integrate the roles and interests of all the different actors and stakeholders, a reasonably stable, well-founded regulatory environment is an integral part of the solution to our energy problem. A strategy for using the full scientific and technical resources of the Nation--private as well as public--in order to make the transition to a new energy era must surely give a prominent place to the role of regulation.

A similar point can be made for the economic regulation of electric and gas utilities. Whether R&D can be charged as an expense or whether it must go into the rate base has a major influence on the incentive of utilities to carry out R&D. Similarly, the structure of regulations affects the incentives of utilities to invest in decentralized energy sources, such as solar and small-scale hydroelectric power.

A similar argument can also be made for the structure of regulations governing the leasing of public lands. How this is done affects the incentives to develop energy sources, such as oil shale or oil and gas from the outer continental shelf.

A good example of how government regulation affects the course of R&D in the energy field is the impact of the Clean Air Act on the development of the catalytic converter. For years several industrial companies tried with no success to sell the auto industry on the idea of installing a catalyst in the exhause of their automobiles to complete the burning of the fuel and reduce air pollution. Upon passage of the Clean Air Act which required a reduction in auto effluents, a market was created for the catalytic converter. In short order a major business was established creating thousands of jobs and large investment opportunities in production of catalysts, ceramic substrate, and stainless steel containers and in installation and maintenance of the converter. This stimulated the economy, adding to the G.N.P. but more importantly, it contributed to protecting the health of the Nation.

Yet we seem to be lacking the institutional capacity to put regulation into a strategic context. The agency charged with "solving" the energy crisis is the Department of Energy--not the agencies with regulatory authority over the areas I have mentioned. We tend to associate strategies for using science and technology with federal R&D efforts only--failing to appreciate the influence of federal policies, other than R&D policies, on private R&D.

Yet if we are to insure that the course of technological change is consistent with national objectives, we must also understand the influence of federal policies on private decision-making. Thus, we must give explicit attention to strategies for using science and technology that are truly national. This clearly requires that we formulate our technological goals so that they are consistent with other public policy objectives, such as social equity and health, safety, and environmental protection, and devise means to achieve these goals. This is a challenge, to be sure. But it is a challenge that we have not yet really tried to meet.

I have touched on only one aspect of the energy issues, but I believe it suffices to illustrate the two points that I am trying to make--the influence of federal policies and the need for strategies. I have illustrated my points with examples from any one of a number of areas--transportation, waste management, housing, and so forth.

The existence of a federal role in each of these areas indicates a public value which the unaided marketplace would not provide. Yet the mere existence of a public policy objective does not suffice to insure that the creative scientific and technical resources of the Nation will be effectively marshalled to achieve that objective. If explicit consideration is not given to setting and meeting technological goals consistent with those public policy objectives, then technological change may well follow a course both unintended and undesired.

Envisioning ways to incorporate this kind of strategic approach for using science and technology into the decision-making processes of the federal govenment poses a major challenge to all of us. Yet recognizing a problem is the first step toward solving it. Thus, I hope that my comments here today might move us a little closer toward more effectively using science and technology to achieve the objectives of our society.

R&D IN INDUSTRY

Moderator: N. Bruce Hannay *(Vice President, Research & Patents, Bell Laboratories)*

Speakers: Wesley A. Kuhrt *(Vice President--Technology, United Technologies Corporation)*

Edward E. David, Jr. *(President, Exxon Research & Engineering Company; President, AAAS; Former Presidential Science Adviser)*

Panel of Inquiry

Margery E. Hoppin *(President, National Council of University Research Administrators)*

Charles Mosher *(Executive Director, Committee on Science & Technology, U.S. House of Representatives)*

Richard S. Landry *(Administrative Director, Economic Policy Division, U.S. Chamber of Commerce)*

Markley Roberts *(Economist, AFL-CIO Research Department)*

Robert L. Stern *(Director, Business/Government Relations, The Conference Board)*

R&D in Industry

Topics addressed during the session included:

- *Industry-university cooperation in R&D.*
- *Industry-government cooperation in R&D.*
- *The quality of the statistics on R&D in industry.*
- *Multinational corporations, foreign investment, and technology transfer.*
- *The effects of economic policy, patent policy, and regulatory policy on R&D in industry.*

Introduction

N. Bruce Hannay

Vice President
Research & Patents
Bell Laboratories

The subject of this afternoon's discussion--R&D in industry--is one that is currently getting a lot of attention. I would like to broaden the title just a little by saying that the attention is not only to R&D but also to innovation. The coverage of these two subjects by newspapers and magazines in recent months is unprecedented. It is rare that this much attention is paid to the technological side of industry.

I would like to make the distinction between R&D and innovation because there is a difference and it will be important to the following discussions. R&D is where the process starts, but after you have the idea and you know what the technological advance is to be, there are quite a number of other things that have to be done before that idea is transformed into something that can be delivered to the ultimate user in the form of services and products. And a major portion of the cost of the whole innovation process is found beyond the R&D state.

There are a number of forms of innovation, of course, but a useful distinction can be made between two major categories. One is incremental innovation, which indicates a rather small step forward. It is based upon past technology and refers to some incremental improvement in the product or the process by which the product is made. More fundamental forms of innovation result in major new forms of goods and services, as for example, the numerous products resulting from the invention of the transistor.

The importance of innovation is to be found in several areas. One is that it does provide new technological answers to problems of society. We can often measure our progress in terms of innovation. Innovation also affects the economic health of the country. A number of research studies have investigated the connection between R&D and innovation and the economic prosperity of the country, and while it is very difficult to prove the point completely, there are strong indications that there is a correlation. Various aspects of the economy reflect innovation. One is the balance of payments, and the so-called high-technology fields generally have a favorable balance of payments and low-technology fields generally do not. Another area is productivity. Economists are fond of saying that all innovation leads to increases in productivity, but this simply isn't true. There is a large area of overlap, but they are not identical terms. However, productivity is a fundamental measure of economic progress, and innovation is essential to steadily improving productivity. Innovation also affects employment. As new industries are formed, the economy grows and provides new employment opportunities.

The signs that the rate of innovation in the United States has been lagging are to be found in some of the economic indicators just mentioned. The balance of payments is very unfavorable at the present time. The growth rate of productivity in the United States is the lowest of any of the Western developed countries. It is lower than the United Kingdom, which is next to the lowest. The number of new venture companies based upon new technological ideas has been drastically decreasing in the last few years. Five or six years ago, hundreds of new companies per year were being formed and established through the sale of equity. In the last two or three years, the number has been progressively smaller, close to zero. There has been a decrease, according to NSF figures, in the constant dollar totals being supplied by industry for basic research, which tends to be the longer-term research that is some measure of the possibility for major innovations. Furthermore, research in industry is highly concentrated. Only a few industries, indeed, only a few companies, have established basic research programs. Even total R&D is concentrated in a few industries.

The most important aspect of innovation to my mind is that the quality of innovation has been diminishing. There has been an increasing tendency on the part of industry to take a short-term outlook, to seek incremental innovations rather than fundamental innovations. I am not saying that incremental innovations don't have their place, but they are not likely to produce the benefits to the country that will flow from the more fundamental type of innovation. It is very hard to put a quantitative measure on the quality of innovation and the evidence therefore may be somewhat suspect. My only evidence has been gained largely from talking with my peers in other companies and finding out what their attitudes were about the state of affairs. Some companies are still strongly exhibiting a long-term outlook, but not as many as there should be.

Faced with these discouraging trends, Washington has responded with considerable interest. The Office of Science and Technology Policy and Frank Press, the Science Adviser to the President, have been very concerned and have been discussing this state of affairs with a number of industrial people to try to assess what indeed is happening with respect to industrial innovation. As a result, a domestic policy review of industrial innovation has been authorized by the President. The study will be conducted by an interagency committee headed by the Secretary of Commerce. Jordan Baruch's office in Commerce is working with OSTP and has the responsibility for preparing a set of policy options for presidential consideration, on ways to address issues and problems bearing on industrial innovation. This study is by no means the only activity in the area. The Experimental Technology Incentives Program at the Bureau of Standards is a small program that has been concerned with the problem for some years, and Jordan Baruch's office has been interested in industrial innovation in its proposals with respect to cooperative technology programs. A number of people in the

Congress and in its associated agencies like the Office of Technology Assessment and the General Accounting Office also have expressed interest and concern about industrial innovation. It is quite clear that Washington would like to do something, although it is not entirely clear what it is that needs to be done.

In all of these activities and deliberations it is generally understood that supplying more R&D dollars will not solve the problems. In fact, the R&D totals in industry are up in terms of constant dollars; it is the way that these dollars are being spent that is the real issue. Still, Washington often thinks that the easiest fix for this kind of problem is to spend more on R&D. That, however, would address the symptom rather than the underlying causes.

What does industry say the underlying problems might be? The two major ones are: the financial climate that industry faces, and regulations. First, let us mention several aspects of the financial climate. Inflation causes research and other investments for the future to be very expensive. The cost of money affects the ability of companies to obtain the capital that is necessary for innovation. Recall that I said that R&D is the cheap part of the innovation process. The expensive part is what comes after--putting the plant in place to manufacture the product or deliver the service. Capital formation has become a major problem for many industries and it certainly affects the decisions of what they do. Tax policy is another part of the financial climate that affects investment in technological innovation. Some aspects of it are favorable, some aspects are unfavorable. For example, the capital gains tax has had an unfavorable affect in discouraging new venture companies, as I mentioned previously. The main problem, of course, is that the future financial climate is uncertain, and investment in new innovations and new plants is not likely to bring returns for several years. Therefore, investors shift to a short-term strategy that will bring returns soon.

The second major factor cited by industry is regulations, which take several forms in the health and safety area. Here, too, uncertainty about the future course of regulations is a major problem. In addition, regulations are imposed in the absence of complete scientific knowledge about the hazards that are being regulated and the consequences of the regulation. And there is no followup mechanism for going back and looking at those regulations after they are imposed. Regulations impose a cost burden. Industry devotes considerable capital and R&D resources to meet regulatory requirements--resources that must be diverted from the development of new products and processes. I do not mean to imply by these statements that regulation is not desirable or necessary, but regulation, as viewed by industry, is a very imperfect process. Some of the money that is spent to meet regulatory requirements is well spent, and some is not.

In summary, probably the most troublesome aspect of regulations and the financial factors is the element of uncertainty. One doesn't know what the future will bring and therefore industry tends to move to a short-term strategy rather than the long-term strategy that is required for real breakthroughs.

Other areas of concern to industry are antitrust laws (for example, cooperative research between companies) and patent policy (such as federal policy with respect to ownership of patents derived from federally supported R&D). All of these matters will be considered by OSTP and the Commerce Department in the domestic policy review.

What will be the outcome of these studies? Well, it is hard to know. Clearly it is much more difficult to do something about the general regulatory climate in the country then it is to institute a new R&D program. Remember that the regulatory and financial measures have been instituted with a purpose in mind other than innovation. It becomes difficult, therefore, to change these just to encourage innovation. However, industry and government might propose reasonable changes, which would keep the essential benefits for which the policies were constructed in the first place while allowing the effect on innovation to be much more favorable. Industry must be cooperative and constructive in this process. Government at the same time must provide encouragement rather than disincentives to initiative in enterprise. A hopeful sign is the receptivity in Washington to discussions of the subject. During the meeting today I hope that we can illuminate some of the issues that I have mentioned briefly, and arrive at some constructive ideas on what might be done.

With those rather long introductory remarks, I will now introduce the two speakers.

Wesley Kuhrt is Vice President--Technology of United Technologies. While at United Technologies he also has been President of the Sikorsky Aircraft Company and before that Director of Research at United Aircraft. He is an aeronautical engineer from MIT.

Edward David is President of Exxon Research and Engineering Company and President of AAAS. His prior positions *include Executive Director of Research, Bell Telephone Labs; Presidential Science Adviser and Director, White House Office of Science and Technology; and Executive Vice President of Gould, Inc. He received degrees in engineering from the Georgia Institute of Technology and MIT.*

Prepared Presentation

Wesley A. Kuhrt

Vice President
Technology, United
Technologies Corporation

I'm delighted to be here today, because this promises to be a fascinating session. We have a respected moderator, a worthy subject, and most of all, an 18-page compass to guide our discussion. The chapter on industrial R&D in AAAS Report III has the refreshing tang of authenticity. The issues it raises are real issues. The questions it asks are the kind you can hear in most industrial research laboratories and in many corporate boardrooms. Consider this sentence from Section B: "There is a growing body of opinion that the hallowed category of basic research is not very helpful in the analysis of R&D in industry."

The authors go on to suggest that it might be more meaningful to talk about long-term and short-term research in industry, rather than basic research, applied research, and development. When I read those words, I nodded so hard that my glasses slipped off my nose. What's more, I decided to devote my entire 15-minute summary to a few of the issues implicit in this statement. I believe they cut to the heart of the broader topics we are considering today.

To begin with, the notion that industrial research can be neatly trisected into a basic phase, an applied phase, and a development phase is an anachronism, particularly when applied to a corporation that makes products with high technical content. The development cycle for a new product--a turbofan engine, for example--may last two decades as the product is brought from conception, to manufacture, and on through several stages of improvement in later years.

New knowledge is added every step of the way. Consequently, knowledge-building is an integral part of the development process, and it is often performed by the engineering professionals responsible for development.

How much of this knowledge-building is basic research? How much is applied? According to the latest estimate from the National Science Foundation, about twelve percent of industrial research fits the well-known definition of "original investigations for the advancement of scientific knowledge which do not have specific commercial objectives." These studies account for three percent of industry's total R&D expenditures.

Is three percent enough? Or, should industry devote more of its R&D dollars to basic research? These are popular questions, but I feel it's more productive to ask if industry is spending enough money on knowledge-building programs that will help maintain our nation's leadership in technological innovation.

The kind of programs I am talking about have time as their common denominator. They involve years or even decades of sustained effort that advances the state-of-the-art. I doubt that specific commercial objectives lurking in the background diminish the value of the knowledge gained.

At United Technologies, for example, we have a long-term research effort to develop jet engine turbine blades made of single-crystal alloys. As you know, these exotic metals offer high strength and excellent resistance to oxidation at elevated temperatures. Our Pratt & Whitney Aircraft Group recently announced that single-crystal alloy components will be used in the new JT10D turbofan, an advanced technology engine that will power the next generation of jetliners. The manufacture of practical single-crystal parts hinges on very precise solidification technology. Our earliest research in this area dates back to the early '60s. We've walked many technological steps to be where we are today.

Another example is the use of lasers in metal processing. We think it's possible to produce unique metallurgical structures that have exceptional physical properties with the help of laser beams. Essentially, the method involves the rapid melting and almost instantaneous cooling of thin alloy films. It's still early in the day for this technique. There are many problems to be solved, including the design of suitable alloys, and the development of a practical production process.

Knowledge-building is an expensive business. Industrial R&D calls for the investment of substantial corporate resources, frequently with little assurance of payback or profit. During 1977, United Technologies spent more than $368 million on company-funded research and development. That was equivalent to 6.6 percent of our total revenues for the year, and 187 percent of our after-tax income.

With this expense comes risk. In fact, the spiraling costs of industrial R&D mean that the technical risks inherent in funding substantial research and development programs are as real, and as threatening, as the risks of launching new products in the marketplace. A failure at any point can jeopardize the whole investment.

When you consider our present economy, it's not surprising that many industrial corporations are turning away from risky long-term research programs. It's far easier to justify short-term programs, where the rewards are closer, and technical risks are simpler to control.

Inflation puts a two-way squeeze on long-term research. The price of R&D climbs, and so does the cost of every other corporate necessity. Long-term programs, with their distant payoffs, are less able to compete for available corporate funds. Belt-tightening can lead to myopic vision. Long-term research is diluted, or postponed, or scrapped outright.

Having said this, let me add that short-term research is not inherently less noble than long-term research. Both kinds of knowledge building are essential to the growth of technological corporations. Both can make powerful contributions to society, and to a company's bottom line. There must be a balanced mix of long-term and short-term programs, a mix that supports corporate goals. And this leads me to another point.

The role of research and development in industry has changed in recent years. Industrial R&D has matured beyond its traditional function of a long-range contributor to corporate growth and has become a real-time contributor to corporate profitability and survival.

Today, American industry faces many tough problems that threaten its ability to remain in business: problems such as energy shortages, environmental concerns, and skyrocketing raw materials' costs. These problems must be solved by research and development. They must be solved now by short-term R&D.

Another good reason for short-term research--one that is frequently understated--is the need to continually improve existing products. Product improvement is an evolutionary process that often consists of a chain of short-term R&D projects. Though the technical risks in each project may be small, the total cost over several years can be enormous.

The Pratt & Whitney Aircraft JT10D turbofan I mentioned earlier is a fine example. We've estimated that a half-billion R&D dollars will be spent by the time the engine is ready for airline service in the early 1980s. But, we expect to spend another half-billion dollars over the 10D's lifetime for improvements and refinements that will keep the engine competitive and cost-effective during the years ahead.

As you know, achieving an efficient balance between long-term and short-term programs can be difficult. At United Technologies, we believe it's essential to integrate R&D planning into the overall corporate business planning. We call this process Research Management.

The result of coupling technical and business planning is a new perspective on company operations that enables our technical and corporate managers to look ahead at the anticipated benefits of our industrial R&D programs. Specifically they can judge whether or not the planned programs adequately support the company's business objectives. They can ask the kinds of questions that lead to maximum resource utilization and minimum technical risk.

Are the goals of planned R&D programs supportive of corporate strategies? Are critical projects being postponed or simply overlooked? Are company activities that need technical support receiving it? If not, what additional resources are necessary to meet the needs?

Do we have a workable mix of projects designed to develop new products, build new knowledge, and improve existing products? Are proposed programs sized in keeping with their anticipated benefits? Are key projects underfunded? Are less important projects oversupported? Are there any dead-end programs in the plan?

A comprehensive coupling analysis pinpoints R&D activities that are absolutely essential to reaching commercial objectives. Though these projects are on the critical path, and often carry maximum technical risk in case of failure, they may be small in size and low in perceived priority. Identifying them in advance is the first step in managing technical risk.

Our coupling analysis also helps us achieve a good balance between technology pacing and technology utilization in our R&D programs. In other words, it helps us decide if we should push the state-of-the-art forward with our own research, or else make use of state-of-the-art technology pioneered by someone else.

All of this means that R&D planners must have access to front-office business information, including commercial objectives, long-term marketing plans, and financial planning data. Sharing information in this way helps ensure that our research and development programs are balanced against the needs of the marketplace that we serve--the marketplace that ultimately supports our R&D efforts.

I've used the word balance several times this afternoon: the balance of short-term and long-term industrial R&D; the balance of technology pacing and technology utilization; the balance of research and development efforts against the needs of the marketplace. Balance, I believe, is essential to the vigor and effectiveness of industrial R&D. It is the key to the technological innovation that all of us want.

Prepared Presentation

Edward E. David, Jr.

President
Exxon Research &
Engineering Company

Messrs. Shapley and Phillips have provided a comprehensive review and analysis of R&D in both the federal and private sector, and have produced a valuable reference. I also note that they correctly reflected the difficulties inherent in assessing industrial R&D. The statistics on industrial R&D provide an overall view of the magnitude of the effort, an indication of trends, and an approximation of how the industrial R&D dollar is split among basic and applied research and development. They also facilitate comparisons between what stockholders and taxpayers are spending on R&D. It is helpful to have this kind of information, and I commend them for having done an excellent job under severe constraints, particularly the difficulties of obtaining adequate data.

But input statistics by themselves do not tell us anything about the quality of R&D, about past results, or future prospects. For example, what has been the ratio of successes to failures? Has there been much or any high risk, high payoff, effort undertaken and, if so, how did it come out? How good is R&D management? What new insights have been achieved? We know what the R&D cost, but have no measure of value received or opportunities lost. Further, because R&D is one of the early steps in the innovation chain, even if we knew about R&D successes, we still wouldn't know about the crucial result, that is, whether a technical achievement was converted to a commercial success.

Furthermore, statistics are subject to multiple interpretations. For example, I am uncomfortable with conclusions that might be drawn from macroeconomic comparisons among nations. It has been suggested that the recent unfavorable trade gap which exists between us and the non-OPEC nations results at least in part from a decline in our technological capability and leadership. I doubt this assertion. When we look closely we find one of the root causes of the unfavorable non-OPEC trade balance has been the difference in growth rates between us and our trading partners since the last recession. We simply grew faster than our trading partners and, thus, increased our imports faster than they did theirs.

Nevertheless, our trade balances could and should be better. Technological innovation would contribute directly by improving the competitiveness of our goods and services, and indirectly by helping to offset inflation and stagnant or decreasing productivity growth. Unfortunately, technological innovation is itself a victim of inflation and stagnant productivity is induced by other forces. Many are a consequence of government policies, which discourage capital formation. Furthermore, while innovation is highly dependent on R&D, successful R&D alone is not a sufficient condition for greater innovation. The impact of successful R&D is easily blunted by downstream roadblocks to innovation which can be many and varied, such as too expensive capital, ill-conceived or poorly implemented government rules and regulations, and eroded patent positions. Such influences have produced what might be called "the decapitalization, bottlenecking, and expropriation of the intellectual property of U.S. industry."

So, while the statistics on industrial R&D are interesting and give us a feel for overall magnitude of national effort, they do not provide a firm basis for alternative national policies to influence innovation, or even to see clear trends. If we cannot lean too heavily on the statistical evidence, how do we address these questions?

There are some fundamentals to guide us. First, the health of industrial R&D hinges upon a market for its product. If the product is not used in one way or another, there won't be industrial funding. Here lies the importance of my remark about decapitalization, bottlenecking, and expropriation. Current assessment of industrial markets for the R&D product indicates a substantial shrinkage. Thus, the statistical increase in funding by industry for R&D should be regarded with some suspicion. For example, the redesign and restyling of automobiles for a new model year hardly adds to the fund of new knowledge, new technique, or innovation. Yet funding for that purpose is included in R&D figures from industry. Somewhat more appropriate for inclusion in R&D spending statistics is the discovery and utilization of a new lubricant additive which decreases residual friction between sliding surfaces. Of undoubted R&D value is industrial support of inertial-confinement fusion experiments. The point is that changes in the macro-index of industrial R&D spending yield dubious conclusions because important effects can be masked by inappropriate aggregation. Without an evaluation of R&D markets, macrostatistics are very suspect. As far as I know, there has been little effort investigating the market dynamics. The IRI and NSF surveys of R&D manager's opinions are helpful but not definitive. However, the judgments found in these surveys are bearish. Another early inquiry into the market is McGraw-Hill's survey which this year included a question about new product aspirations (not performance). The results were somewhat bullish. Overall, industry says it will spend thirty-three percent of its effort on new products this year compared to twenty-six percent last year. Again, it's difficult to know how to assess these figures, for it is easy to claim new product aspirations. The term, "new products" has become a shibboleth because investment bankers and portfolio managers consider new product research a key indicator of future corporate performance, which in turn translates into stock price increases. Also, such percentages say nothing about the availability of venture or small-business financing which has not been healthy in recent years. So, I come back to the fundamentalist view that market for the R&D product is a controlling factor in the health of the S&T enterprise, and that market is closely tied to capital expenditures and the severity of bottlenecks. If we're to learn about industrial R&D, we must know about the market for its product.

This discussion leads to another fundamental which tends to be more academic. It is a market-oriented classification of R&D, and focuses on the permutations of new and old markets, new and old products. For example, a new product in a new market is much higher risk than a new product in an old market. R&D on an old product in an old market may indicate product improvement or a better production process giving lower costs, and needless to say still lower risk. The McGraw-Hill survey begins to get at this kind of analysis but more knowledge along these dimensions would help us draw valid conclusions about industrial R&D. Also, I should compliment McGraw-Hill for its industry-by-industry breakdown of R&D costs. That adds some insight into what's happening.

A third important fundamental involves basic research. It seems clear enough to me that from the macro-point-of-view that industry will not increase its basic research spending very substantially. This opinion is tied to the above thoughts about markets. Only the largest corporations support basic research consistently. That has been true since the demise of the prestige-oriented laboratory syndrome of the early 1960s. Furthermore, the large corporations are under attack; regulatory agencies and stockholders are asking for accountability based on relevance.

Despite this dour inside industry outlook, I take heart from one set of statistics that appears in Chapter 3 of our document; that is the set which shows that total university R&D funded by industry has been growing in both current and constant dollars. I am not satisfied because the current level totals only about $150 million a year. I would like to see a much larger number, and I think that the opportunity for industry sponsorships of university research is unparalleled--witness the Harvard-Monsanto agreement which sets a remarkably cooperative tone. Support by industry of excellence in research and education is indeed relevant to industrial objectives. This fundamental is clearly one to be attended to if our industrial innovation is to be healthy.

A fourth fundamental is that government's R&D objectives are much broader today than some years ago. Basically government has a legitimate concern with R&D for national defense, security of supply for commodities, and the economic health of the nation. These wide concerns bring the government into civilian R&D deeply. This trend holds substantial dangers. For example, the government can become involved where it has little institutional capability for market assessment. Thus, the government may fund research which is not effective, and at the same time discourage the private sector from financing its own more effective research based on market understanding or entrepreneurship. I believe there is a sort of Gresham's law operating: government money for R&D tends to drive out private funding. Just how large this effect is becoming needs to be quantified. Generally, when government is not the direct user of technology--as it is in, for example, military and space programs--it is not in a position to properly and effectively steward the R&D. This can lead to throwing money at a problem and when solutions are not forthcoming, there is disenchantment, despair, and, on occasion, a witch hunt.

I believe some of these problems are beginning to be recognized, particularly in the Congress. The Federal Grant and Cooperative Agreement Act of 1977, which provides a new framework for joint R&D efforts between the government and the private sector is a very important first step. It establishes a legitimate basis for distinguishing between situations in which the federal role is that of purchaser and user of technology via a procurement contract and situations--expected to grow in frequency and importance--wherein the government and the private sector work in concert as partners. As cooperators, the private sector's contribution in terms of technology, management, commercialization and financing can be adequately recognized in the cooperative agreement, even though the government's financial contribution may be larger. This sort of arrangement seems to have a far better chance of success in producing useful R&D results than the more traditional arrangements. Exxon, EPRI, Phillips Petroleum, ARCO, and a Japanese industrial consortium have entered into a cooperative agreement with DOE to continue the development of a coal liquefaction process, and so far we are pleased with the way the agreement is working. More use of such instruments for government-industry cooperative efforts is warranted if innovation in critical subjects is to be encouraged.

A final fundamental is an integrated innovative chain. The existence of a vigorous innovation system including both large and small businesses is essential to a healthy economy. That fact is spoken to in our AAAS document. Much has been written and said about barriers to innovation, especially those set up by government, and I will not repeat that litany here. I am aware that as a result of Dr. Frank Press' efforts, the President has directed a major study to be undertaken promptly to define the issues and problems which bear on industrial innovation. I also understand that

Dr. Baruch will have a leading role in that activity with substantial industry participation planned. As a culmination of the vast amount of previous study of innovation, this new study is a good omen.

I have a recommendation to make concerning the study. If truly useful results are to emanate from this activity, the study ought to recognize the named fundamentals plus others. A gathering of macro-statistics followed by macroeconomic studies will not contribute to either of these objectives. I urge that a leaf be borrowed from the business schools, and that the case-study method be used, followed by a careful analysis along fundamental lines. Almost every industry has its own horror story about how efforts to bring new technology to market were frustrated by regulatory, economic, environmental, and other factors which often have their roots in federal laws and government policies. The case histories need to be accurately documented, fully delineated, and carefully analyzed if we are to ever get at the roots of the poison trees. A large number of industries should be covered by these case histories as, for example, drugs and pharmaceuticals, nuclear and other energy, steel, chemicals, automotive, textiles, electronics, computers, and so on. It may be that even among the horror stories there will be some pleasant surprises which will provide positive clues for the development of improved policies. I also recommend that a parallel effort be initiated to get a better understanding of how other systems in other countries operate. As Ezra Vogel commented in his most interesting article on Guided Free Enterprise in Japan: "Because of its poverty of resources Japan had to devise a superior system in order to make a place in the world. In view of the fact that Japan is gaining or overtaking the U.S. in so many industries, is there not some merit in understanding the mechanisms that have created its success?" I am not recommending that we adopt anyone else's system. I am urging that we understand the strengths and weaknesses relative to our own system.

To sum up, I do not believe that we need to be apologetic about our research and development activities. A nation whose citizens represent nineteen of the thirty-four Nobel prize winners in the Sciences in the last five years has much to recommend it. Further, our market-oriented system has delivered a style and quality of life that is the goal of many the world over. Lately, there has been much tinkering with the system, most of it with the highest motivation. I do not believe the results have been net positive. One effect has been to reduce the market for R&D results. That will eventually impact negatively R&D

funding. That trend must be reversed if we are to avoid the ride down Kondratieff's economic roller coaster for the next fifty years.

Discussion

Margery Hoppin, in discussing the relationship between R&D in industry and universities, referred to Edward David's desire for more linkages between the two. She noted that such linkages are occurring more frequently in the highly concentrated industrial areas in the Northeast and California. University-industry cooperation is not yet widespread, however, and a number of mechanisms might be used to increase it. First, the development of a brokerage role between industries and universities is needed. A federal agency might serve this function by reviewing proposals, providing information on R&D programs to industry and university groups, and linking industries and universities with similar interests. Second, companies need to come to the campuses to discuss their interests and research needs, perhaps at regional symposia. Third, certain industries, particularly the major R&D investors, might put out guidelines on how and when universities could apply for research support. A fourth need is the development of better contracts or cooperative agreements between industries and universities so that proper payment is arranged and patent, licensing, and publication rights are within the framework of university as well as industry objectives. Some of the impediments to industry-university linkages at present involve patent rights and the granting of exclusive licenses for the development of some of these patents. Lastly, to help universities in the development of patents, seed money is needed for prototype models of inventions. Often only a critical few thousand dollars are needed.

David agreed that there are problems with respect to university-industry cooperation. The problems were faced in a very unique and successful way in the agreement between Harvard and Monsanto. Based on this agreement we should have great hope for more cooperation in the future. Harvard is a university known for its independence, and Monsanto is known for its proprietary outlook. If they can agree, then there is hope that others can also while maintaining their independence.

One participant mentioned, in relation to the talk of industrial returns on corporate investment in basic or long-range research, that what is often overlooked are the intangible, immeasurable benefits of coupling into the scientific community. Such connections may enable the company to be the first to take an initial discovery from the scientific community and turn it into a product. This participant told of his personal experience at Raytheon which, after the laser principle was discovered, was the first company to come out with high-powered lasers. He told how the research staff, by frequently attending specialized symposia, had been kept alert to new developments in science.

Tom Jones of MIT said that the relationship of the universities' research programs with government needs to be improved. The current indirect cost-recovery picture at the universities is very different from the time when universities had relatively small research activities and allowances for indirect costs were very small--20-25%. Now, in accordance with government document A-21, which defines what is allowable as indirect costs, indirect cost rates in general are up to 50-70% of the direct wages and salaries. Even at this level, the costs are not nearly covered; those who have figured industrial indirect costs will recognize those figures are rather low. Among the differences with industry are imputed interest and allowances for exploratory research. The lack of support for exploratory research, or independent R&D, has put the universities in the very tight box of having virtually no way to instigate really new areas of technology which would have significant industrial spinoffs. At the moment the universities' only recourse is to raise private money, obtain money from industry or use their own resources. The granting agencies--NSF, DOD and the others--generally like to see that something is already shown to be a pretty good bet before they will become involved with their own funds. David added that one of the problems universities will face in conducting basic research is the impending change in federal government rules for what is to be considered reimbursible overhead. The result will be to decrease coverage of the overhead, and thereby increase cost to the universities when they perform basic research supported by a government grant. This puts more financial pressure on the universities, and they can't afford it.

Michael Michaelis of Arthur D. Little commented on the means to stimulate innovation through industry-government cooperation. He began by referring to David's prepared remarks which praised industry-government cooperative agreements as having a better chance of producing useful R&D results than more traditional arrangements. In mentioning the cooperative agreement between Exxon and DOE, David referred to the Federal Grant and Cooperative Agreement Act of 1977.

Michaelis noted that the law, if interpreted appropriately by OMB in setting guidelines and then by the federal agencies, provides an exceedingly important framework for relationships between the federal government and recipients of federal funds who are engaged in R&D not aimed at federal missions such as defense and space. (The Office of Technology Assessment has issued a thorough report by John Young on the background and implications of the act.) The legislative history of the act points to the relationship between the federal government and state and local governments, but it also contains the clause "and other recipients," defined as profit-making, non-profit-making, and individuals. OMB has placed the emphasis on state and local governments in its interpretation. At the moment the act is a sleeper, but it may be directed into channels that would be exceedingly productive in stimulating innovation. David affirmed that John Young's report is excellent, somewhat esoteric, but extremely useful. He hopes OMB takes note of it in its interpretation of the act. What Young basically said is that cooperative agreements should be used when the principal aim is for the private sector engaged in the R&D to commercialize the product or service, and that procurement contracts should be used when the product or service is to be consumed by the federal government or its agencies. David agreed with Michaelis' view that the act might be an entirely new institutional instrument for dealing with civilian R&D.

The previously mentioned agreement, between the federal government and Exxon, effectively entitles the government to half of the future income from the licensing of an Exxon coal liquefaction process. The government has the right to use the process for its own purposes. If there is any licensing to commercial companies, and surely there will be if the project is a success, and if there are royalties, then the government will share in the royalties according to its total investment. The private sector funding for this project is $120 million which includes, as indicated in David's talk, participation by Exxon, Electric Power Research Institute, Arco, Phillips Petroleum, and a Japanese consortium. Federal funding is also $120 million. This kind of arrangement--where people are effectively investing in development and getting rights and returns from that investment based on its success, and where the management and technology remains on the private sector side--is an extremely important mechanism. Michaelis asked David whether the agreement actually works as the act embodies it, with both parties having an essentially equal voice in negotiating the direction and manner of conducting the R&D and in the subsequent stages. David replied that there is an elaborate advisory and review activity in which the federal government and all participants are closely involved. There is close stewardship of what is going on, what is to be done, what the time scales are, and what the funding is going to be.

A question was raised concerning David's references in his prepared remarks to the dangers inherent in making macroeconomic comparisons, to the detriment of the U.S., between other national economies and that of the U.S. David reiterated that the balance of trade "problem" comes primarily from the fact that our largest trading partners, Japan, for example, have had slow recoveries; hence their imports are at a low level. David just visited Japan and talked to many people, both inside and outside of the government. He found that the only element of growth in the entire Japanese economy was the export market and that most of their exports come to the U.S. As a result, the U.S. at present has a large negative trade balance with the Japanese. David added that during the last seven and a half years the U.S. has been through two recessions. As any economist will say, productivity tends to decline or at least productivity growth tends to be low during a recession. An additional factor accounting for low productivity in the U.S., which goes beyond the economics of the moment, is a lack of capital investment.

Stern added emphasis to a point David made about R&D input statistics: they rarely reveal factors of utility or quality of the output. In view of the outcry there has been over the last two years about what is happening to U.S. basic research, Stern examined the available statistics. As a share of total U.S. R&D, basic research has held practically constant from 1963 to the present. In 1963, 11.5 percent of R&D was devoted to basic research; in 1968, 13.5 percent; in 1977, 12.6 percent. How can one say that basic research is being de-emphasized?

There have been allegations that industry's share of basic research has gone down catastrophically. As reported by NSF, in 1968 industry provided 16 percent of all the basic research dollars; in 1977, 14.6 percent--not a large drop. However, in the last ten years, industry's performance of basic research has decreased significantly. In 1968 industry performed 19.4 percent of the nation's basic research; in 1977, it was down to 15.2 percent. This decline is perhaps more significant, especially when one notes that, in 1963, industry performed 26 percent of the total basic research. This suggested a look at the relative role of industry as a performer and as a source of funds for basic research.

Industry's ratio of "performer to source" has changed from 1.20 in 1963 (that is, 20 percent of the money coming from outside sources, primarily federal) down to 1.04 in 1977. Industry is now more or less on a self-sustaining basis in basic research; there is a bit of granting to the universities--on the order of $150 million--and there is a little bit that industry takes in from the federal government. The major decline has been in the amount industry receives from the federal government for support of basic research, and perhaps that is what the R&D policy-makers should be revisiting. Stern cautioned that such aggregated data don't reveal all of what has happened and what is happening in individual industries.

Stern noted, as had Press and David, that there are no good indices of the quality of research output, whether basic or applied. Measures such as patents or numbers of publications have generally been found to be of limited value. There are some current efforts at the National Bureau of Standards to find measures of "innovativeness." If one could know under what conditions people, institutions, and dollars can produce more innovative results, one might be able to devise better guidelines for R&D policy.

Other limitations in the data available to us as a basis for policy-making are underlined by a joint study by NSF and the Bureau of the Census. For the third consecutive year, the Securities and Exchange Commission has required companies to report the amount spent for R&D in the 10-K statement. A comparison was made between what was reported as R&D expenditures by corporations to NSF/Bureau of Census and what was reported to the Securities and Exchange Commission. The study showed that of the 100 largest R&D performing companies responding, only one third reported the same R&D spending--within plus or minus three percent--to the two data collecting agencies; eighteen percent differed by ten to twenty-five percent; nineteen percent by more than twenty-five percent. There may be some differences in the definitions of R&D used and reporting requirements may be slightly different, but these variations are beyond what the technically trained policy-maker would like to have in his data. The study also showed that, if instead of looking at industry groups, one looks at individual companies, the discrepancies are greater; the stronger the lens the more scatter one sees. In view of these findings, maybe more time and effort should be spent on examining the quality of R&D rather than the quantity.

Frederico Welsch of the Worcester Foundation for Experimental Biology commented on Stern's implication that there has not been a decrease in basic research. Welsch said that NSF reports that over the last decade, in terms of constant dollars, the U.S. is spending eighteen percent less for basic research. Two large programs, one of which is NASA, have been substantially reduced. Stern replied that one must be careful in looking at statistics. One of the problems is the definition for basic research; it may not be the same today as fifteen years ago. Specifically, there were a number of years in which almost the whole NASA budget was termed basic research, later years when much was called applied research. If definitional problems were carried to their extreme, one might call all NASA work developmental; after all, Newton had described the gravitational law and the rest was just good engineering. The point Stern made was that today and roughly ten to fifteen years ago approximately the same share of the nation's R&D dollars were said to be going to basic research. Therefore, he did not find it completely believable that there had been a radical decline in the conduct of basic research as is implied by Welsch's statistic, an equally valid number it should be noted. These are two aspects of the same issue.

Charles Falk of NSF asserted that while statistics are only one tool in policy decision-making and in planning, they are useful. One must look at what lies behind the statistics, how and why they were collected, and their limitations. Just because two sets of statistics from two government agencies don't agree is not cause to use neither one of them. One should examine the reasons for the discrepancy to determine whether either set of data might be useful. If there were no good reasons for the differences, then one should not use either. He went on to say that NSF is aware of some of the limitations of the present taxonomies for industrial R&D. Some of the recommendations which have been mentioned during the colloquium will shortly be introduced into the NSF statistics. For example, industry R&D statistics will include a breakdown of long-term and short-term R&D, as compared to basic and applied research and development. Depending on what one is analyzing one taxonomy may be of more use than the other.

David praised Falk's statistics and the conclusions that Falk draws from them. Statistics must not be allowed to detract attention from the real problems of basic research, however. An example of a real problem would be the anticipated changes in the regulations concerning what constitutes reimbursable overhead in basic research grants to universities from the federal government. The debate over whether percentages or absolute funding best represent the trends in spending for basic research is a pseudo-problem.

Markley Roberts emphasized the importance of the overall economic situation as an influence on R&D and innovation. As David mentioned previously, there is a need for markets to serve as stimuli for R&D activities. The economic situation, leaving aside what is done by the federal government, has an overriding significance for what gets done by industry. It is obvious that industry is looking to the future, to markets, to profits. An expanding, healthy, full-employment economy provides incentives and resources for research and development. An expanding economic and social pie provides the cushion needed to alleviate problems and tensions that arise from dislocations caused by technological change. Union representatives have an obvious and direct concern for the jobs of union members and thus talk much about full employment. However, full employment is vitally important for the health of our society as a whole. The future of the economy is much more important to the future of R&D than what the federal budget for R&D happens to be.

An effect of R&D on the economy, in turn, was brought up by David. He told of a thesis done by a student at Columbia concerning the causes of stagflation. This student opined that stagflation resulted from a "pass-through" economy--it has become the habit of industry to pass through cost increases rather than try to minimize the cost of production. If we could get people to start investing in new capital equipment and to develop better production processes, costs of growth in production would be constrained rather than be passed on to the consumer. Wesley Kuhrt described how the costs of raw materials, which have been increasing two to five percent faster than the average rate of inflation, have caused United Technologies Corporation to do research in manufacturing methods. They now manufacture in different ways so that fewer "chips are left on the floor." In several areas the benefits were far greater than anticipated.

Roberts cited figures from the AAAS R&D report on the concentration of industrial R&D activity in a relative handful of giant corporations. While 1,200 corporations are responsible for about ninety percent of private industry R&D, the top 100 account for seventy or eighty percent, and the top 8 account for about thirty-five percent. Even without considering the social implications of economic concentration in our country, more thought should be given to the pros and cons of this concentration of R&D. Bruce Hannay responded that it would be desirable for a great many companies, beyond those that do R&D now, to undertake more R&D, particularly basic research. However, that does not mean that the big companies should be discouraged but that the small companies be encouraged; R&D would then become less concentrated.

David added that it is almost a tautology to say that the concentration of R&D is in the largest companies. They have the money to invest and are encouraged to do so by the federal government, their boards of directors, and their stockholders. Furthermore, they can afford to take substantial risks if there is the possibility of commensurate return. There is no way around the present situation unless the federal government were to be so unwise as to create R&D corporations, which might be something like the federal contract research centers, or perhaps the government-owned-contractor-operated firms. These corporations would do all or a large fraction of the R&D for the private sector. Nobody believes this would be a good idea. The supposed R&D concentration problem is not a problem at all, but is merely a numerical outcome of the risk-taking pattern of industry where the largest firms take the largest risks.

Roberts brought up the topic of technology transfer, particularly the situation where the multinational corporations transfer technology overseas and in some cases sell the technology outright. An outstanding example related to national security was the sale of the Thor-Delta rocket and launching system to Japan, giving away at bargain prices some of the most valuable technology the U.S. has. A second example is the fact that all of our videotape cassettes now come from Japan, using technology developed here in the U.S. An American businessman in a May Fortune magazine article said that we are killing ourselves by exporting our technology. Jack Baranson,[1] in a study of 25 cases of technology transfer in the chemical engineering, consumer electronics, computer, aerospace, and automotive fields, concludes that decisions made by U.S. corporations in their own self-interests regarding the sale of industrial technology do not necessarily coincide with and protect the interests of the U.S. economy. All of this U.S. capital investment overseas--close to $150 billion--is investment that did not take place in the U.S. and is one part of the explanation for our productivity slowdown. Roberts added that the world is complicated, and it is difficult to regulate the export of technology, but one can't avoid a problem just because it is difficult to handle. In a democracy, a government has the right and the duty to regulate exports of technology in the interests of society. He is concerned about what has happened to the structure of our economy as a result of a large part of our manufacturing sector suffering both loss of production and loss of jobs. What goes along with this is a loss of skilled workers, and a loss of being on the cutting edge of new technology. The real problem areas for our country are international economic competitiveness, national security, living standards, and human welfare. To improve in these areas we need a healthy, diversified economy.

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[1] Baranson, Jack, "Technology Transfer: Effects on U.S. Competitiveness and Employment," prepared for the Bureau of International Labor Affairs, Department of Labor, Conference on the Impact of International Trade and Investment on Employment: The Department of Labor Research Results, December 2-3, 1976. (Developing World Industry and Technology, Inc., Washington, D.C.)

Sam Raff heads a task force of the Institute of Electrical and Electronics Engineers concerned with innovation in electrotechnology, particularly U.S. innovation. His group, like Roberts, views the export of technology as a serious problem. U.S. companies receive $2.6 billion each year from patents and royalties abroad. If the patent and royalty rate is approximately the same overseas as in the U.S., that represents at least twenty times that much in sales. That is, $50 billion worth of products are being produced abroad with our patents and technology. Raff doesn't know what can be done, within the constraints of the democratic process, to regulate technology export, but we should examine some of the present regulations and the rules of the DISC's (Domestic International Sales Corporation) to determine if they are favoring such export.

In response to the criticisms of technology exchange, Hannay noted that the flow of technology is not easy to control. There are many ways by which technology moves, including the open literature. One can't just turn it off. Furthermore, it is a two-way flow; technology also comes in to the U.S. The consequences of trying to control the outward flow would include risking a cut-off of the technology we receive.

David disagreed with Roberts about the facts of the case of the videotapes and home videotape recorders. David mentioned that these products were developed from Japanese technology; the home videotape recorder was developed independently in Japan by two different companies. The efforts in this country, while technologically very good, could not be marketed. The Japanese admirably solved the major problem of quality control of the tapes; we had more trouble in the U.S. In addition, David does not agree with the notion that a major part of the effort of multinationals is to busily transfer technology. Most companies prefer not to transfer the technology but to sell products. They merely use the technology as an entry point to foreign markets when there is no other way. David felt that Roberts overstated the problem when he called the Thor-Delta rocket "the most valuable technology we have," and that it was a "giveaway" to Japan. The technology was ten years old when the agreement was signed. It is now eighteen years old, and clearly obsolete. Furthermore, it was hardly a giveaway; the McDonnell Douglas Company, which held the basic patent rights, received very large payments from the Japanese government. The pieces of the rockets, assembled in Japan, are still being made in California, giving employment to a very large number of aerospace workers. Thus, while investment of U.S. capital abroad may hurt our balance of trade, it does result in a return of a substantial amount of money to this country that improves our balance of payments. The U.S. corporations may risk expropriation by a foreign government, but in many cases there has at least been a payback to the corporations by that government. The money returned is in turn available for investment and capital. With wise investments, there can be a net gain for the U.S.

There are two laws on the books that regulate exports very effectively: The Export Administration Act administered by the Department of Commerce and the Munitions Control Act administered by the Department of State. Some people would say that though they are generally administered very well, U.S. export policy is too conservative and holds back things that should be made available to foreign countries on a businesslike basis. If we don't make them available, other people will, and their societies will obtain the benefits.

Roberts suggested that federal tax policy is not an inhibiting factor for R&D investment. He feels that adequate funds for R&D are available, and that the tax laws that allow R&D to be currently expensed provide an additional incentive. David disagreed. Expensing R&D doesn't help at all when a corporation happens to be in a loss position. With the downturn in the economy a large number of corporations are now close to, if not in, such a situation.

Continuing the discussion of tax policy, Roberts brought up the point that to a degree our tax system encourages overseas investment through the tax exemption of foreign-earned profits. There is thus an incentive for the U.S. corporations not to repatriate profits, resulting in further overseas investment of the unrepatriated money. That of course has a negative effect on investment back in the U.S. Incentives for overseas investment also arise through tax credits and the DISC. Congress did tighten up the DISC loophole a bit but that was in the 1974 trade act; the tax system is still geared towards supporting such investment. Although repatriated profits are subject to tax, David maintained that a large percentage of the profits of U.S. corporations abroad are repatriated regardless of the tax laws. One must ask the question: If a change were made in the tax laws, how much additional profits would be repatriated? Most of the analyses show that it would be rather small. David was confused by Roberts' mention of a DISC "loophole." The DISC is in fact an effort by the U.S. government to stimulate exports, not to stimulate U.S. investment abroad for production. If anything the "loophole" should be made larger if what is wanted is the export of products and not technology.

Several participants addressed the subject of patent policy. Roberts suggested that present policies discourage the diffusion of R&D. The AFL-CIO is particularly concerned about private patents being granted on innovations funded with federal money; such patents should be in the public domain. Even if one doesn't agree with that position one should recognize the need for more consideration of the effect of our present patent policies on the diffusion of knowledge and technology. Hannay responded that present policy, which often requires patents resulting from federally supported R&D to remain in the public domain, is ineffective. What belongs to everybody is of interest to no one. A company will not undertake the expensive task of turning a patent into a commercial venture without some protection against others entering the market much more cheaply afterwards. An alternative patent policy is desirable, one which would give exclusive license to somebody interested in spending additional funds to utilize a patent resulting from federal R&D. Tom Jones of MIT, using an example from university research, also expressed the view that public title to these patents, as has been proposed by Roberts, Senator Nelson, and others, would stagnate technological development. One of the most successful of the university patents was the memory core for computers developed by Dr. Forrester. The income from this patent has been stated in the public press to be above $20 million and is in fact only slightly below that. Some saw it as a steal from the government, but estimates show that the government benefited. The memory core was a great boon to U.S. industrial technology and gave the U.S. computers the push needed to dominate the world for a couple of decades.

David stated that the diffusion of R&D is not restricted by patents, but in fact the opposite occurs. If there weren't patents, then all of the proprietary information would be company secrets; there would be no diffusion at all except through leaks. The patent system provides a way to make the knowledge and techniques available to all comers, usually at a modest fee except in extraordinary cases. Large corporations, particularly, feel that they must license for a reasonable fee. Leon Green, a consultant for the General Atomic Company, pointed out that large companies don't need the protection of a patent; they can resort to secrecy and have all the resources to exploit the knowledge and technology they discover. Patents are what make the Route 128 phenomenon possible--the growth of small companies started by individual investors and entrepreneurs. The patent is what such a person takes to the bank to get financing for his company. Route 128 grew up on defense contracts because the Defense Department has a very enlightened patent policy; it lets the developer take title. Since the formation of NASA and DOE, both of which have keep-title policies, the diffusion of technology has slowed down. One recommendation on promoting innovation through government action would be to have all government departments adopt the same patent policy as DOD.

Welsch of the Worcester Foundation noted that non-profit institutions have had an institutional patent agreement with the federal government for some time. The patent counsel for HEW reported that until 1968 not one product from research supported by NIH had been brought to the market. In the last ten years, with the introduction of the patent agreement, 60 have been brought to the market, and 200 more are in the process. At present, however, the institutional patent agreement is in danger of being terminated.

Stern commented that everyone is encouraged by the fact that Press and Baruch are undertaking a study to look at innovation in American industry. While not knowing the structure of the study yet, the fact that some fifteen government agencies will be the coordinators of the effort leads one to worry that the study may not look equally intensively at the roles of private industry, universities, and government. The study should be pitched at the national, not the federal, questions. The respective roles of the many aspects of our economy and society should be considered. The innovative small company deserves attention. While this sector is difficult to quantify and illuminate, it is one of unusual productivity, where the payoff per unit of input has been very high. Lawrence Kushner of the National Bureau of Standards noted that in discussions of industrial innovation a number of government policies are always cited which in their present forms seem to exercise a depressing effect on innovation. The Baruch study will examine these policies with a view toward their possible modification. Kushner wondered what the effect of such modifications would be in the absence of a substantial improvement in the economy, which would provide markets and demand to draw forth the innovation. What is the relative importance of changes in federal policy, as compared to the general economic climate, in influencing innovative activity? David responded that changes in policy would not have an impact independent of the economic climate. However, the time constant for innovative activity is much longer than for changes in the economic cycle. Averaged over a substantial period of time, improvements in policy would result in a substantial increase in innovative activity. Hannay added that a very complex environment determines whether innovation does occur. There is no question that people would vote for a healthy domestic economy as the primary item. Nevertheless, there are still other factors that have an effect.

Stern pointed out that the economic conditions within which our innovative system works now are radically different from ten or fifteen years ago. The obvious factors of inflation, devaluation of the dollar, increased energy cost, balance of payments problems, declining corporate profitability, and cost-accounting questions having to do with allowable depreciation rates, change the "coefficients" of productivity of an R&D-like activity.

It is difficult to say to what extent changing federal policies have affected R&D and innovation because of all the other factors influencing what goes on in industry. The change in conditions surrounding the R&D enterprise is illustrated by a recent review, primarily among companies belonging to the Industrial Research Institute. In that group, R&D investments are getting an increasing amount of attention from top management. The R&D manager has less discretion and is forced to compete in the allocation of funds with other corporate functions offering alternative uses of the available capital. Another example of the changing R&D environment is the diminished appeal of the glass-enclosed, pure science research center on a rocky mountain crag--the popular metaphor in the 1960s; even in those days, such centers may actually have had little payoff in terms of output, but they did have a payoff in the price of the company's securities. The effect on R&D from such changes in the R&D climate may be greater than the effect of changes in federal policies; we just don't know; we must continue to analyze, test and speculate.

Kuhrt gave examples of how companies have changed in their management of R&D based on his own company's experience. He said that there is a much greater emphasis being placed on the planning function, and that technical as well as financial planning are exposed to the highest level of management. Such a procedure is well integrated into the process of coupling technical and business planning, as mentioned in his prepared remarks. Within his company the policies related to the type of devices which are patented or the level at which one has to give up the rights to the work conducted (DOD work, for example) do not have an effect on the level of emphasis placed on R&D, whether long- or short-range. The level and emphasis of R&D is far more affected by the business analysis the company conducts. There is a certain percentage of what is called subject-oriented research (long-range research) that does not have a specific application to any of the products. Such work is conducted because there is evidence of long developments that have paid off. One example mentioned in Kuhrt's speech was turbine blades made of single crystal alloys, a development which is almost twenty years old now. The laser field provides another example of a long development that has had considerable payoff. These would not have been affected by any of the government regulations that have been discussed.

R&D AND INTERNATIONAL ECONOMIC COMPETITION

Moderator: **H. Guyford Stever** *(Corporate Director & Consultant; former Presidential Science Adviser)*

Speakers: **Stanley H. Ruttenberg** *(President, Ruttenberg, Friedman, Kilgallon, Gutchess & Associates)*

Arthur M. Bueche *(Vice President, Research & Development, General Electric Company)*

R&D and International Economic Competition

Topics addressed during the session included:

- *Comparison of U.S. technology and investment in R&D with practices in other countries.*
- *The effects of international technology transfer on domestic employment.*
- *The impact of U.S. technology and R&D on our international competitive position.*

Introduction

H. Guyford Stever

Corporate Director
and Consultant

Ladies and gentlemen, distinguished head table guests, and participants, it is quite a pleasure to be here. The subject before us this evening is interesting to me because of my job as a liaison officer in Dr. Bush's outfit during World War II. In that capacity, I was in London trying to bring British and American science and technology together for the war effort. Thus, my career started in a period of absolutely unbelievable cooperation and exchange, and I can reminisce about giving away international secrets at a very rapid pace. However, I also remember that the instant the war ended, there was a tremendous change in the atmosphere surrounding technology and industrial secrets. We had won the war and were going back to a different arrangement.

Most of my generation grew up in an unusual time with respect to international economic competition and the position of R&D. For two decades after that war we had an unbelievable scientific and technological advantage while the other countries were recovering from the blows to their economy, industry, research and development sectors, and science and technology. I have a feeling that many Americans of my generation suffered very much from that unusual experience. We really should enjoy the memory of it and recognize that today we are in a different time.

Tonight we have two speakers who are very well qualified to speak on the subject of R&D and international economic competition.

Stan Ruttenberg is President of Ruttenberg, Friedman, Kilgallon, Gutchess & Associates, an economic consulting organization. He has worked as the Director of Research for the AFL-CIO, served as an assistant to the Secretary of Labor, and later became Assistant Secretary of the Department of Labor under President Johnson.

Arthur M. Bueche is Vice President of Research and Development at General Electric Company. He received his Ph.D. from Cornell in 1947. He then worked for three years as a post doctoral student on the rubber program, a hangover from World War II, after which he went on to General Electric's Research Lab.

Prepared Presentation

Stanley H. Ruttenberg
President
Ruttenberg, Friedman, Kilgallon, Gutchess & Associates

I approach this evening's session with a bit of trepidation. I am an economist in the midst of scientists, engineers, research and development people. I am not a scientist. I really know very little about research and development as such, and I am going to approach it from my own point of view and my own vantage point. I am one who believes in stirring up controversy and getting a discussion started. I gather that we are going to have a discussion after my associate and I finish. I make this opening statement with that in mind.

There is probably nothing that poses a more serious threat to the United States economy and to the ability of the economy to produce jobs for all U.S. workers who want and are able to work than the rapid diffusion of technology around the world and the resulting dissipation of the U.S. technological leadership. Controversial enough, yes.

I would like to divide my discussion on these problems into four areas. First, what is happening in the development of U.S. technology. Second, why is the U.S. technological advantage deteriorating. Based on what I've been told about the discussion this afternoon, I know there is some controversy as to whether that is even true. Third, what is the impact of the current trend in technology development and transfer on employment in the United States. And fourth, what might be done to correct the situation and restore the U.S. ability to create enough good jobs for all the workers who want jobs.

First, let us look at what is happening to technology. As I said, I am no expert on technology. Others are better able to provide more detailed information to you. However, here are some important developments that are public knowledge that must be kept before us as we proceed. According to reports and statistics, American investment in research and development is lagging. Data Resources, Inc. did a study on the role of high technology industries and economic growth. Their conclusion was that research and development is suffering "from malnutrition." The percent of GNP going into

R&D has declined over the past decade from roughly three percent in the mid-1960s to about two percent last year, although I see in the AAAS Report III that there is some question as to whether that two percent in the last year is correct and that there are some adjustments in that figure. But it suffices to say that whether our GNP proportion going into R&D has gone down or is remaining steady, it clearly has not gone up, while West Germany and Japan, to say nothing of the USSR, have made substantial gains in research and development expenditures. Yes, we are spending more than the rest of the world in dollars, but proportionally we are spending less.

A second point under this first category--what is happening to technology--is the decline in the U.S. lead in major technological innovation. A study by Gellman Associates of 500 major technological innovations introduced between 1953 and 1973 showed that although the majority were still developed by the United States, the U.S. lead has been declining. In the mid-1950s eighty percent of these new innovations were American; by the mid-1960s they had fallen to fifty-five percent. The type of research that the U.S. industry concentrates on is aimed at improving efficiency of operations, and not new and different fields of commercial endeavor. Certainly a lot of effort these days is devoted to defensive research in response to environmental problems and safety and health regulations. I am critical of this trend, and yet I understand that the cost and problems involved in meeting these new requirements are very important.

In addition the pace of technological transfer has accelerated. Co-production arrangements, incentives for foreign investments, licensing, royalties, current key plant operations, joint ventures, and multinational corporations (I will have a little more to say about them in a while.) are all serious problems that have to be looked at in terms of the U.S. competitive position in the world and the role of technology relating to that. As we all know, the book value of U.S. investments overseas since 1970 has almost doubled from $75 billion to almost $140 billion. Fees from licenses and royalties have doubled from $1.5 billion to $3.75 billion in a ten-year period ending in 1976. The U.S. has entered into co-production arrangements for armaments; General Electric has an arrangement with Rolls Royce; and sophisticated electrical devices are made overseas in Taiwan and Korea. We need to know more about the impact of these phenomena on the domestic economy, and I urge you not to rely upon the conventional wisdom to make your judgment.

These transfers of technology occurred because of U.S. production. The advocates of the general theory of comparative advantage and international specialization of production must be wondering what is happening to their theory as we see technology move continuously around the world. I wish I had more time in my remarks to develop this further, but I'll leave it as a categorical statement that I hope will stimulate you to ask questions.

Let us move on to the second category: Why is the U.S. losing its technological lead? What brings it about? Technology is being transferred and the multinational corporations that are getting more than half of their income from overseas operations are growing. Many of you will say that is good. I would say a great big question mark. Incentives to develop technology and production capability in the United States are no longer as great as they used to be. Yes, certainly capital flow and capital formation are important and I wish I had time to discuss that problem. I will if there are questions that come to me. In my view the multinational corporations and especially the flexibility that international organization and operations give them have played a major role (1) in accelerating the pace of technological transfer, (2) in the decline in U.S. research and development, (3) in the deterioration of the U.S. technological lead, and (4) in the loss of the U.S. competitive position. But, I don't blame it all on the multinational corporations by any chance. There is no government policy to deal with these problems, and what government policy there is encourages transfer of capital investment and technology from the United States. Our tax laws and tax deferrals, tax credits, and transfer pricing and all that goes with it play a role. The U.S. government does, it seems to me, very little about the problem.

Now my third area: What is the impact of the loss of technological leadership on our international competitive position? It will have an impact on the ability of the United States to adjust to changing trade patterns, on our ability to shift to higher technology industry, and on the rate of productivity rise in the United States and consequently, also on the state of growth of the United States economy. As important as it is to have a free flow of technology around the world and to assist the developing world with that technology, without a growing world economy, engaging in unnecessary transfers and capital flows will destroy our own economy and do little for the economies of the developing world. The theory that the U.S. need not worry about job displacement because we are a high technology country is no longer true. A good deal of our high technology goes through a life cycle before it is transferred to Europe or the Far East or to the developing world of sometimes one or two years and in some instances of even zero years. This compares with the life cycle for domestic-based development of technology where the product is produced in the United States and the transfer of the technology occurs only after it has been well developed over a period of years in the U.S. The consequences of our inability to shift to high-technology industries are a loss of jobs and of high-technology products to export that will pay for our oil, our raw materials, and our food items. In addition, export of technology and deterioration of our high-technology industries will reduce the rate of productivity growth in the United States. Productivity in high-technology industries grows at a far more rapid rate than that in low technology industries. This loss of technological leadership leads to slower rates of economic growth, lower rates of employment growth, and higher unemployment. The sequence of these steps bodes ill for the U.S. economy.

In the last few minutes, I would like to deal with the fourth category: What needs to be done about the problem? Here I would like to read you a quote from Jack Baronson, Professor of International Business at the University of North Carolina: "These trends [loss of productivity growth and economic growth] make it essential for U.S. industry to maintain technological lead through investments in R&D and commercialization of technological innovations within the U.S. production system, distinct from the tendency to move abroad as it becomes difficult to maintain productive competitiveness within the United States." The U.S. cannot afford to become a rentier economy, such as Great Britain has, through exporting our industries, exporting our capital, and exporting our technology. All of this produces returns on investment from direct investments overseas, plus fees for royalties and interest on capital loans, but these returns will not permit the American economy to grow and provide the jobs that are necessary. Do we want to follow the dangerous road of the British experience, with its economy and unrestrained export of technology and capital? I think that we are on the way to it, and I'm not sure how to avoid it. But I plead with you, don't think of the conventional wisdom as the way to respond to these problems. Think through the whole problem and ask yourself what impact there is. Whatever is done, we need to act now while there is still time to reverse the trend, a trend that if left unchecked could spell disaster for the U.S. as it has for England. We must take steps to maintain economic growth, protect the U.S. economy from exploitation, encourage technological development and full utilization of such technology by U.S. industries.

Several positive measures are worthy of consideration. There must be greater support for R&D in the United States. Government support for basic and applied research efforts are important and the FY 1979 budget of President Carter does propose a slight increase. As stated in AAAS Report III, however, and I quote: "The administration believes, however, that private investment in basic research is critical to the overall national effort and that industry also should seek to strengthen its level of support." And then the report goes on to say that "hortatory advice from Uncle Sam" is one thing; maybe "another nudge" will help but the "real world effect if any remains to be seen." In addition to increasing direct government support for R&D through grants and contracts, tax incentives that are pinpointed to research and development expenditures also are needed.

The rate and pace of technological transfers by multinational corporations is terribly important and we must do something about slowing it down. Two of the things we might consider are to require technology exporters to secure a license--oh, terrible government regulations involved in that--and to file an employment impact statement--terrible, terrible. But it would permit objective consideration of technological export, a consideration not now exercised by the United States. Most of the developed countries of the world already are moving in this direction; Japan, Canada, Sweden, France and Australia have one form or another of controls on technological exportation. Specific information is difficult to obtain, however. It is a shock that in this man's government in Washington I cannot find out what the developed countries of the world are doing in the area of control or lack of control on the export of technology. It seems even more difficult to find out in this government what kind of incentives, if any, governments in developed countries are using to encourage research and development. Those are problems that we ought to look into and look at very carefully. Present incentives for export of technology need to be removed. Tax credits, tax deferrals, excess tax credits, transfer pricing, accounting rules all encourage overseas investment.

I would like to close by reading to you one further quote from the AAAS report: "The problems /international trade protection/ are aggravated by various built-in incentives to U.S. multinational companies to export technology and move production operations abroad and by subsidies and other forms of assistance foreign governments give to their companies competing with ours." Technological innovations are really the key to our future. We need to provide support and incentives to American industry to move away from its defensive research. Many resources have been allocated to meeting our safety, health, welfare, and environmental concerns. We need to be concentrating on doing the kind of research that is essential to keeping the U.S. a high-technology country that is capable of absorbing workers who might otherwise be displaced. In the process we must be sure that stimulating increased innovation doesn't result in rapid exportation of the technology thereby destroying its ability to develop America into a competitive economy.

Prepared Presentation

Arthur M. Bueche

Vice President
Research & Development
General Electric Company

The phrasing of our topic--"the impact of R&D on the competitive position of U.S. industry in world trade"--reflects continuing concern about our nation's declining advantage in R&D, about international competiton in high-technology products, and about our disastrous balance-of-payments situation getting worse as we shell out $40 billion per year for foreign oil.

Of course, if that's not enough, we're also worried about the declining value of the dollar abroad, about continuing inflation at home, about the stalemate in the fight against unemployment, about taxes on taxes on taxes, about our potentially disastrous energy situation, and about the incredible national lethargy about it.

So we don't really need any more harbingers spreading gloomy news. We've got the morning paper, the evening television, and politicians of all persuasions speaking in between.

Frankly, I'd rather talk on the more positive side. As people engaged in R&D--you and I as members of AAAS, for example--we've got a lot to be proud of. For instance, over the past twenty-five years, technology has helped this country generate thirty million new jobs. And U.S. exports of high-technology products increased more than four times from $12 billion in 1966 to $51 billion in 1976.

Technology also has helped make U.S. agriculture the acknowledged leader in feeding the world, and agricultural exports last year provided an $11 billion plus in balance-of-payments to at least help offset the $40 billion deficit from foreign oil. Medical care may be more expensive, but it is also more effective, and life expectancy in this country continues to rise--from 68 years in 1951 to 72 years in 1976.

United States technology--that is, our nation's leadership in science, innovation, and good old American known-how--has indeed accomplished a great deal.

But it obviously hasn't done enough. And what is worse--much worse--there are indications that, as a nation, we are going to have difficulty maintaining a leadership position. For instance, our performance in patented inventions is perhaps one of the best single measures of what's happening in terms of R&D output. The fact is that the number of patents granted to United States residents declined by twenty-one percent between 1971 and 1976. At the same time, patents to foreign residents grew by sixteen percent and became thirty-seven percent of all United States patents granted in 1976.

And even though our past technological advantage has helped overcome the potentially disastrous effects of our oil imports, the trends are disturbing indeed. For example, United States imports have been forging ahead of exports since 1975. In the meantime, our share of world manufacture exports has been shrinking, from twenty-four percent in 1968 to twenty percent in 1977 (excluding exports to the U.S.). It is interesting to note that if we had held on to that twenty-four percent world "market share," we would have overcome a large share of the deficit caused by our 1977 oil imports.

Our discussion topic tonight, of course, centers on research and development--the R&D that is the important first step in the innovation process. So let's look at what is happening to R&D:

- In constant 1972 dollars, the nation is still spending less than its peak in 1968.

- As a percent of GNP, we are now spending only two percent on R&D compared with a high of three percent in 1964.

- What's more, we are losing position to major foreign competitors in terms of R&D as a percent of GNP. And the figures don't tell the entire story, because half of the U.S. federal R&D funds are for defense. In Japan and West Germany, by contrast, the R&D budgets for defense are minimal, and virtually all of their R&D funds are aimed at promoting economic development and the advancement of knowledge.

- Our estimates indicate that Japan alone--with less than one-half the population of the United States--may have by now as many engineers and scientists working in that type of activity as we do. And while our effort appears not to have grown between 1970 and 1976, Japan's effort increased by fifty percent--from around 160,000 in 1970 to about 240,000 in 1976.

As for strictly federal expenditures on R&D, we should note that:

- Federal support of R&D in constant 1972 dollars is still lower than its 1967 peak.

- Even though there is a highly touted increase in next year's budget for "basic" research, the rate of increase requested by the President is actually less than this year's. In FY 1979 the requested rate of increase is only 10.9 percent, compared with 13.4 percent in 1978.

- Federal energy R&D is up--by 1.4 percent to $3.3 billion for the fiscal year, and defense R&D is up 9 percent to $13.8 billion. But let's remember that this nation's defense is now largely dependent on the import of foreign oil, obtained by means that are essentially non-defendable in the event of a real military attack.

So let's not delude ourselves that, as a nation, we are spending a truly sufficient amount of our dollars on the kind of technical work that has--in the past--made possible our traditional growth in productivity, international leadership, and living standards at home.

I'm not going to belabor the point of the direct connection between technology and economic progress. It's a favorite subject of speakers today. But I would like to emphasize the very close-to-home matter of providing jobs for people.

A recent study by Data Resources Incorporated has shown that over the past ten years, high-technology companies in the U.S. increased employment nine times faster than low-technology companies, and these same high-technology companies increased overall productivity by about four percent per year, or twice the national rate of two percent.

Perhaps right here in this discussion, while we're talking about high technology and jobs, is as good a time as any to lay to rest that old myth about how exporting technology causes unemployment at home.

There's usually no problem getting agreement that exporting products is good for America, although the relative importance of high-technology products in this regard is sometimes overlooked.

On this subject of exports and jobs, I hope you will forgive my using a company with which I am most familiar as an example, but in the absence of any substantive analytical data in the literature, I have no choice. We've made a rather extensive study of GE experience.

In the past four years, General Electric's "exports" have quadrupled from $606 million to $2.3 billion. Frankly, we are proud of the fact that we are the largest single industrial contributor on the positive side of the nation's balance-of-payments ledger. But the point I want to emphasize is that the major share of our exports is comprised of high-technology items. And let me remind you that this isn't a matter of dollars alone. It's also a very vital issue of jobs. Our company's exports account for some 44,000 GE jobs in the U.S.--about one-seventh of our total employment--and 47,000 jobs for our U.S. suppliers.

But what about this matter of exporting our technology--of working closely with our overseas affiliates?

The creation of affiliates in foreign countries is frequently the only way that U.S. companies can gain an export foothold in those countries.

The governments of many of our major commercial rivals have put in place policies that limit the purchase of American high-technology products. These nations have an understandable desire to develop their own capability in these fields. American companies have to play by their rules, or not play at all. Furthermore, the real competitors are in Germany, the Netherlands, and Japan. If we don't get the orders, they will.

In our own company, we have found that working with foreign affiliates is an absolutely crucial means of increasing exports of our domestic products. For example, since the opening of a chemical venture in the Netherlands, we've increased our total sales there from $3 million per year to $29 million. And I could cite many other examples.

Again, the payoff is not only in overseas sales, but also in American jobs. Our company's International Sector estimates that the "pull-through" effect of affiliation overseas--that is, the demand created by overseas affiliates for components and materials "made in USA"--accounts for nearly 30,000 U.S. jobs. And most of these opportunities are, once again, in the high-technology R&D intensive areas.

Another comment seems appropriate in regard to this matter of international technology transfer. I fear that many of us tend to look at this issue with a bias created during a very special period--the era between the end of World War II and the late 1960s.

During that period, America was able to "go it alone" technologically. Our main potential rivals had an uphill effort to recover from the war. At the same time our own R&D effort was growing rapidly.

Such a situation could not continue indefinitely. Even if the U.S. had maintained its R&D effort at peak levels, our relative world role would have declined, although not as dramatically as has been the actual case. It is estimated that more than sixty percent of the R&D in the "free world" is performed outside of the U.S.

The point is that, to an increasing extent, foreigners have been coming up with good ideas that America can and must use. We can hardly expect them to transfer this technology to us if we don't transfer something of equal value to them.

Given the inherently international nature of all scientific and engineering disciplines--"no country, nationality, or race has a monopoly on good new ideas"--a world of jealously guarded "national technologies" does not appear to be in the best interests of anyone.

So it is unrealistic to look for any return to extreme U.S. dominance of world technology.

But that doesn't mean we should just roll over and play dead. Because we just might find out that our competitors are not "just playing."

To summarize:

- High technology--that is, R&D intensive--products and services are our major source of strength in seeking to reverse the very disturbing trends in our nation's balance-of-payments situation.
- The figures make it abundantly clear that our nation's position of R&D leadership is slipping.
- New technology can help provide not only the higher productivity we need to meet international competition--it also can mean more jobs for people.
- International technological cooperation--as well as competition--is essential to national strength and economic well-being.

These are among my beliefs. I look forward to hearing yours.

Discussion

Guyford Stever began the discussion by asking Stan Ruttenberg to expand on his comment that expenditures for defensive R&D ought to have reached their peak. In light of current opinion that industry is increasingly focusing on short-term, defensive R&D and Stever's recent observations of the large percentage of R&D in a major steel company that was devoted to responding to environmental regulations, the comment was especially intriguing. Ruttenberg responded that his comment was based more on a gut reaction and a hope than on any data. The point he was trying to make is that defensive R&D has been important and costly, but that now he hopes the peak is behind us and industry can move forward with more emphasis on long-term R&D that leads to innovation and an increase in productivity and jobs. If defensive R&D expenditures are to remain high, the country must develop some means, other than simply an availability of capital, to encourage industry to maintain a vital long-term R&D effort.

Arthur Bueche used a current decision at General Electric to illustrate what he thinks is needed to strengthen industrial R&D in this country. The top officers at G.E. think that they have a method for increasing productivity. It would cost several hundred million dollars and would require additional highly trained, scarce personnel, but the payoff should be significant. The decision was made to start the project immediately, but not at the maximum rate possible. Why? Uncertainty. The G.E. officials were reluctant to fully staff the project and to marshall all their resources because of the possibility of an economic downturn in 1979 or 1980 and the uncertain regulatory climate. The best way to strengthen technical expertise and innovative capability in the U.S. today, according to Bueche, is to remove some of the uncertainties.

The increase in foreign competition that results from "leaks" of U.S. technology was introduced by a participant who recounted the comments of an industry executive about the unintended "leaks" of technology from company technicians to foreign graduate students studying at a U.S. university. Bueche did not know of a similar situation at G.E., but he did add that he wished university faculty would take more precautions in discussing technology with foreign scientists and engineers. While he does not know the seriousness or magnitude of the threat to U.S. industry posed by possible leaks, he does feel they might possibly be a soft spot in our national security system and deserve to be examined. A participant from Canada felt that it would be impossible to stop the transfer of technology and ideas by graduate students and faculty. Moreover, the economic benefits accrue from the development of the technology into products, and it is the country that does this the best and quickest, regardless of where the technology was initially developed, that will benefit the most. Margery Hoppin added that university faculty should not be prevented from talking freely about their work when traveling abroad; free international exchange is essential to the scientists' pursuit of knowledge. To clear up any misunderstanding, Bueche stressed that he knew of no one who has taken industrial secrets and spread them improperly. What does worry him, however, is the unintentional spreading of industrial "know-how" that may be harmful to our industry or national defense. One university participant cautioned that the divulging of proprietary information by industry personnel to university faculty and students may become a more serious problem if industry-university cooperative research is enhanced. It will be encumbent upon the industry supervisors to brief those personnel participating in research and teaching at universities on information that is sensitive and of proprietary value.

The patent system provides a mechanism for disclosing scientific and technical information while still protecting the developer's exclusive rights to the product or process. Without such a system, industry would use trade secrets and disclose much less. One participant pointed out that industry already uses trade secrets in many cases where a product or process will not reach economic maturity within the seventeen years for which a patent provides protection.

In considering the problem of foreign competition it would be useful to know what other countries are doing to stimulate innovation. Bueche referred to a recent report by the Canadian government on its new program to stimulate innovation. Ruttenberg maintained, however, that in general it was difficult to find such information. An additional problem is the difficulty in determining what other nations are doing once they have granted the incentives for investment. What happens to the innovation? Are there restrictions on how the innovations are to be used? Before we say that we should not have restrictions in the U.S. on the export of technology, we should find out what is going on in the rest of the world. The OECD conducted a study in 1971 that addressed some of these questions indirectly, but did not result in any clear answers.

Ruttenberg asked Bueche how he could advocate the free flow of technology between the countries of the world and at the same time argue for limitations on the disclosure of scientific and technical knowledge developed by industry. Bueche responded by referring to the relationship between technology and products or inventions. He cited examples where peoples working separately in different parts of the world have made the same inventions although they did not communicate. There is a "ripening" of technical knowledge among similar industries, and then they all begin to develop that knowledge into marketable products. Thus, technology only provides lead time at best. The critical factor is to be the first one to capitalize on that technology. The company that does reach the market first must then decide on the best balance between protecting the technology and entering into arrangements whereby it would "sell" the technology to other companies. Protecting the technology too long may allow time for someone else to enter the market with the same invention as a full-fledged competitor, with no benefits to the company that first made the invention. It may be more advantageous to "cut a deal" with other companies for sharing the technology. Making such decisions is the art of managing science and technology in industry.

A lawyer in the audience involved in issues of law and technology transfer cited three cases concerned with the transfer of technology out of the U.S.: (1) Several years ago the U.S. encouraged and supported with several million dollars the development of an extensive research program in Brazil; (2) The U.S. along with several other countries provides support for the International Institute for the Application of Systems Analysis, which conducts R&D on a worldwide basis; (3) Representatives of the Third World have proposed an international code to govern the transfer of technology, which states that the developed nations should give technology to the less developed countries. In response to the last case, Ruttenberg emphasized that the aspirations of the developing world are legitimate, and the U.S. should cooperate with it. But, he stressed that the whole concept of industrialization, of technology for development, has to be within the context of a growing world economy in which the U.S. participates in sharing that growth with the developing world. If we were to rely upon the transfer of technology and sharing in the products of that technology within the current level of demand, we would not only destroy our own industries, but we would not do the developing world one bit of good. This concept must be understood by the Third World countries and by the U.S. as it prepares for the 1979 U.N. Conference on Science and Technology for Development.

A participant noted that the discussion was reminiscent of prior debates in the U.S. and even more so in Britain during the phenomenon known as the brain drain. The brain drain turned out to be not the loss of science and technology, of output of R&D, but the loss of entrepreneurship. Entrepreneurship is essential for the translation of R&D outputs into marketable products and processes. This participant favors no restrictions on technology transfer, except for defense reasons, and feels that if we want to prevent other nations from gaining more competitive advantage over us, we need to be more concerned with improving our teaching of entrepreneurship and not simply focus on issues of science and technology. Bueche added that entrepreneurship was necessary but not sufficient; one still needs the technology and products developed from that technology as the "raw materials." Furthermore, the entrepreneur needs a stable, predictable economic and regulatory environment. A participant from industry elaborated further on the gap between invention and innovation. In the late 60s, it was estimated that in heavy industry there was a lag of twenty years between the development of a new product or process and its introduction into the marketplace. Based on this finding, he surmised that the decline of innovation in the 70s is probably more a consequence of what was done in the 60s than actions in recent years. He concluded with two points: (1) The mix of R&D now is important in determining the rate of innovation several decades from now; and (2) The worst is still to come.

To conclude the session, each speaker made some summary remarks. Arthur Bueche feels that we have a praiseworthy science and technology establishment, but that it could be, and needs to be, stronger. We are still the envy of the entire world; countries still come to U.S. industry for technical know-how and products. But, the aging of equipment and the constraints on hiring and promoting young faculty at the universities trouble him. Also disturbing is our own self-criticism; we are talking ourselves into trouble. We find too many excuses for not moving ahead--litigation, environment, regulations--and this has cast a pall over the whole country. People worry whether a healthy U.S. economy is possible. Without a healthy economy, R&D will suffer, innovation will stagnate, and U.S. business will lose its vitality. To avoid this situation, we must enhance our technological spirit and not allow so many factors to inhibit or deter us from the development of technology. Stan Ruttenberg said that he is in general agreement with Bueche on most issues discussed during the session. Areas of agreement include: (1) high technology industries have a higher rate of productivity growth than low technology industries; (2) R&D is essential for the development of high technology industries; (3) R&D and high technology industries will stimulate economic growth, provide jobs, and reduce unemployment. One point of disagreement, however, based more on intuition and a guess than on available facts, is best described by the question: Are we moving our high technology industries into the U.S. productive system, or are we moving some of them into the systems in other countries? In his prepared remarks, Bueche cited figures from G.E. (he was unable to find any others) to illustrate the positive effect of exports of technology and capital by G.E. on G.E.'s domestic employment. While not disagreeing with the specific data for G.E., Ruttenberg's hunch is that we are not integrating the high technology industries into the domestic economy to the maximum extent possible, which will cause serious problems in the years ahead. In closing, he emphasized the necessity of obtaining more information about the extent of technology and capital exports and their effect on domestic employment.

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R&D AND THE ECONOMY

Moderator: Charles Mosher* *(Executive Director, Committee on Science & Technology, U.S. House of Representatives)*

Speakers: Jordan Baruch *(Assistant Secretary for Science & Technology, Department of Commerce)*

Robert A. Charpie *(President, Cabot Corporation)*

George S. Lockwood *(Founder and President, Monterey Abalone Farms)*

Panel of Inquiry

Margery E. Hoppin *(President, National Council of University Research Administrators)*

Richard S. Landry *(Administrative Director, Economic Policy Division, U.S. Chamber of Commerce)*

Markley Roberts *(Economist, AFL-CIO Research Department)*

George C. Eads *(Program Director, Regulatory Policies & Institutions, The Rand Corporation)*

Thomas A. Bartlett *(President, Association of American Universities)*

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* Mr. Mosher replaced Congressman Mike McCormack.

R&D and the Economy

Topics addressed during the session included:

- *Effects of government regulations on industrial investment in R&D and on formation of high-technology companies.*
- *The relationships among R&D, innovation, regulations, and the economy.*
- *Measures of productivity.*
- *The appropriate federal role in support of industrial technology.*
- *The Domestic Policy Review on Industrial Innovation.*

Introduction

Charles Mosher

Executive Director
Committee on Science
and Technology
U.S. House of Representatives

I have been asked to pinch hit for my long-time friend and colleague, Congressman Mike McCormack of Washington. Mike has to be on the floor of the House of Representatives at the session which begins at 10:00 this morning, so he could not be here. This is rather typical of the life of a Congressman. You are absolutely controlled by forces and schedules that you can't predict, and I know that Mike is very sorry that he can't be here.

Perhaps just as a footnote, I should mention that in this company of experts I am rather self-conscious, being strictly a layman generalist, long-time small city newspaper editor and still a "country editor" at heart. But to the extent that I represent the congressional presence here, maybe it is even more appropriate that I be here than Mike because Mike is one of only two members of the House of Representatives who has any credentials as a professional scientist. He is a chemist and has had a long-time career at the research bench with the AEC. The other member of the House of Representatives who is a scientist is Jim Martin of North Carolina. Harrison Schmitt is the only senator who is a scientist. Those three scientists among the 535 members of Congress in this session are more professional scientists than ever were present in the United States Congress at any one time. This is a significant fact, considering the important role that Congress plays in science and technology policy decisions. The people you ultimately have to persuade on the Hill are generalists such as I. Of course, more than half of us are lawyers. That is a disadvantage as I see it, but something to reckon with always.

Let me now introduce the speakers in this session.

Jordan Baruch is Assistant Secretary of Commerce for Science and Technology. He came to his current post from Dartmouth where he was a distinguished professor of Business Administration. He also has taught at Harvard Graduate School of Business Administration and the Massachusetts Institute of Technology. This academic career is supported by many years of successful experience in industrial management, particularly back in the 1950s and 1960s, and as a very active consultant to industries and government agencies. He is a member of the National Academy of Engineering and the American Academy of Arts and Science. He was educated at the Massachusetts Institute of Technology.

Robert A. Charpie is President of Cabot Corporation of Boston. He has had a distinguished career including positions at Westinghouse Electric, Oak Ridge Labs and Union Carbide, and as the President of Bell and Howell Company. He has been very active on various corporate boards and in advisory groups having to do with energy, invention and innovation. He recently headed a Department of Energy Task Force on the funding and management of demonstration projects. He is a physicist from the Carnegie Institute of Technology.

George Lockwood is a product of the Technological Institute of Northwestern University and of Harvard Graduate

Business School. He has worked in the fields of electronics, ocean engineering, and chemical processing with such firms as the Purine Corporation, Global Marine, and Merck and Company. In 1972 he and his partner founded Monterey Abalone Farms, an aquaculture firm that commercially cultivates abalone. It is a capital-intensive, high-technology company that operates in an environment very much influenced by the government.

Prepared Presentation

Jordan Baruch

Assistant Secretary for
Science & Technology
Department of Commerce

The title of today's meeting is "R&D and the Economy." I am not only going to talk about R&D. I am going to talk about the industrial innovation process, of which R&D is but one component. A great deal of academic study has been done about this process, but let me for the moment define it in a way that differs from traditional economists. When managers, as opposed to economists, talk about industrial innovation, they talk about an entire process that involves ideation, development, use, and diffusion. One of the first things one recognizes when we examine the innovation process is that it is not readily amenable to macro-economic analysis. Certainly there are macro-economic influences, but innovation takes place in the individual enterprise, whether it be a firm, partnership, a proprietorship, or what have you. Innovation is a highly developed, individual kind of action. It is a risk-taking action. It is one that has an uncertain future. And it is one that is conducted by firms or even individuals rather than by an entire industry.

After reading the 1976 NSF Science Indicators, the President asked why industry invests more in short-term R&D than in long-term R&D. He received varied answers from different agencies. I wrote a one-line answer, "Because the effective interest rate has gone up." When he requested further clarification, we explained how the resulting change in discounted cash flow would affect the firm's decision to innovate.

As a result of his inquiries, in May of this year, the President directed that a study be done, not on the barriers to innovation, but rather on the present and possible roles of the federal government in influencing the rate and direction of industrial innovation in the private sector. The task was given to the Secretary of Commerce, Juanita M. Kreps, and she has asked me to design and manage that study.

To look at the impact of the federal government on the innovation process, one must first define "impact" and then decide what we really need to know. As soon as we began looking at policy areas and their relation to the innovation process within a firm, we realized that impact took place in two areas: (1) The ability of the firm to innovate--Does it have the financial and staff resources to do so? (2) The decision to innovate--Who is the decision-maker and what is the rationale behind the decision? Our task then became to identify which option areas would have an impact and where they would have an impact in the process.

There are eight easily identifiable areas of activity of the federal government that have a significant impact on either the firm's ability to innovate or the decision to innovate:

(1) One such area is environmental health and safety regulation. In talking to the business community, one frequently finds that these regulations have a major impact on the ability to innovate. The claims on the discretionary income of the company imposed by regulatory response frequently reduce the budget for research and development. On the other hand, regulation may force innovation in a wide range of industries. Regulation also affects the decision to innovate. In the chemical industry, uncertainty as to future regulations may increase the effective discount rate since the probability of payoff is reduced, and therefore may inhibit innovation. We have a real mix of impacts in this area.

(2) In the financial and monetary area, clearly capital gains tax and other taxes have an impact on the innovation process, again both in ability and decision.

(3) A third area is the direct support of research and development by the federal government.

(4) The procurement activities of the government have an enormous impact on innovation. For example, the Department of Defense is considering procurement support of very

large-scale integrated circuits, which would have a tremendous impact on the rate of innovation in that business.

(5) There are international considerations and influences on innovation: decisions to tax overseas R&D income and R&D expenditures; foreign trade policies; and our import protection policies.

(6) Another area is information and intellectual property: the ability to patent and protect an idea, and the diffusion of scientific and technical information.

(7) Another influence is the social environment for innovation--demographics, labor's participation in the innovation process, and the organization for innovation.

(8) Last, but by no means least, is the area called "industry structure" that includes such things as antitrust policy, competition, and size.

We decided to organize the whole study around these eight option areas and to identify those departments and agencies of the government concerned with each of them.

We immediately faced a problem. Too frequently, studies like this originate in the federal government, develop in the federal government, and end up in the federal government with very little communication with the outside. In the case of innovation, that would clearly be a disaster because we really don't know enough about the actual impact of government on the innovation process in the individual firm. We, therefore, are trying to ensure a broad base of participation in the study. First, we divided the government agencies into the option areas. We also organized four other groups. A group of industrial people will develop a set of papers describing their experiences in their firms as quantitatively as possible. We chose firms for their particular interest or because they were affected by one of the option areas. Dr. Bueche from General Electric led one of the searches and we compiled a large number of nominees for the industry group.

But industry isn't enough. Innovation has an impact on labor, both positively and negatively. It is important that we have a labor committee that both makes recommendations in the option areas, but also reviews the recommendations, suggestions, and observations of the industry people from labor's point of view. We will also have the public interest groups represented to look at these same questions from their particular point of view. And lastly, we will have an academic group. The reason for the academic group is an interesting one. There has been, as I mentioned, a significant amount of research on innovation. We want to have an academic group help set the recommendations of industry, labor, and the public interest groups in a theoretical context consistent with what is already known about the process.

The papers from these four groups will then funnel into the counterpart option groups in the federal government. The tasks of the government groups will be to develop a set of options for the President which can be implemented through legislation, executive order, or by administrative adjustment to influence the rate and direction of innovation.

To enable the President to develop a rational strategy rather than act on a disjointed set of options, we will try to specify what kinds of innovation the options will affect and where each of the options will have an impact. To accomplish this task we will be using a series of descriptors with each of these highly focused options. These descriptors are:

- *Size.* The claim is often made that there isn't enough venture capital for small firms and that the logical thing to do is to roll back the capital gains tax which will then serve as an incentive for financing a small firm. However, such a decision would have a tremendous secondary cost. Many people would benefit who are not involved with small firms. Such options must therefore be focused. If you were interested in fostering new start-ups, for example, one might have a special capital gains rate for founders' stock in a new company. If you were interested in fostering the growth of existing, but very small companies, you might have a special capital gains rate for Regulation A Stock, an SEC regulation for small companies. If you were interested in graduated support for companies ranging from very small to intermediate, you might have a capital gains rate that was proportional to the capitalization, sales or size of the company at the time the investment was made. An option should be identifiable with the size of the company it affects.

- *Structure.* Will the option benefit companies in a disaggregated industry or in an industry with a high level of concentration?

- *Stage.* What is the stage of development of the industry? Is it early in its life cycle or late in its life cycle? Early in the life cycle, we know, there is concentration on product innovation. Later, firms concentrate on cost-reducing innovation. This may seem irrelevant, but let me point out Japan's policy in the television industry. Japan made a conscious decision to foster two types of innovation in the television industry--product innovation in the color T.V. industry and cost-reducing innovation in the black and white T.V. industry. The reason for this strategy is the difference in the stage of the life cycle of the two products. Japan has demonstrated that this strategy works well. Color T.V. sets from Japan compete very effectively with the U.S. television industry, although they frequently cost more than comparable U.S. models. Similarly, Japanese black and white sets compete effectively in price.

- *Requirements of innovation.* Is the innovation capital-intensive or labor-intensive? The latter is highly important for the labor force; the former is structurally affected by capital formation and its costs.
- *Intended market.* What is the intended market of the firm or the innovation to be supported--is it aimed at local or international markets?

I hope that my explanation of the industrial innovation study will stimulate the members of AAAS to comment, critique and offer suggestions to improve the review process.

Prepared Presentation

Robert A. Charpie

President
Cabot Corporation

I have not had much experience with the AAAS, so I want to confess my surprise when I looked over the membership characteristics of the organization, participation on the governing board, and the general selection of topical materials at AAAS meetings to discover this ongoing series of colloquia on the relationship between research and development and the state of the economy. I find, for example, on the governing board only one person who at the moment has any identification with industry, and at a typical meeting about ninety-two percent of the papers are presented by people in the academic and government world. This meeting is an exception and I wonder what the exception proves.

In presenting my views of the basic issues that underpin the relationship between R&D and the state of the economy, I hope that you won't mind the simplicity with which I approach the problems.

It might be instructive to ask ourselves why the government should be interested at all in research and development. It seems to me that there are three missions of government which embrace research and development success in different ways: national security, economic well-being, and societal well-being. Let us examine each of these to see their similarities and differences, and then turn to the company buried within the economy to see how it compares with the government.

A central requirement of national security is the capacity for technological supremacy. R&D has a clear and decisive role to play in knowing what that capacity is and perhaps in acquiring and in implementing it. For this purpose we have created one whole industry in this country and pieces of several more. That industry is a specialized one, and yet it has a heavy impact on all the statistical analyses that I find in the AAAS analysis of R&D. The industries close to national security are very heavily influenced by government funds, spending, and there is a lot of research, a lot of development, and a lot of technical people in those efforts. I would offer a simple rule which seems to apply to that industry, and therefore, causes all of the data which embrace those technical people and technical efforts to bias the total sample of national data on R&D once we make comparisons outside the United States. That simple rule is that if you have money to spend, and you are determined to spend it, someone will spend it for you. The ultimate growth industry is one that is driven by dollar demand, rather than substance.

The second role of the government is economic well-being. We have lived in a period in which we found that what might be called national technological supremacy is a useful tool for economic well-being. The very fortunate simultaneous conditions of strong technology and an industrial base which escaped the ravages of warfare gave the United States in the wake of World War II an incredible edge in the early growth race. Our command and use of technology was, at least to outsiders, one of the important hallmarks and characteristics of our success.

Technology as it relates to economic well-being, is quite different from that related to national security. It is clear that R&D plays an important role in generating the economic or the technological position, but industries concerned with economic well-being are surely different from the massive unified industries which are close to national security--the weapons industry, pieces of the electronics industry, and the aerospace industry. It is also clear that federal action, not related to creation of demand or purchase of products flowing from R&D, plays a very important role. These actions include regulations, tax policies, the very attitude that government takes toward business, the policies in regard to competition, and the extent to which government uses or does not use various control devices. In the last ten years, in particular the last five, searching and penetrating studies of various of these government actions have been initiated to ascertain how they affect R&D, how they affect economic well-being, and which is the cart and which is the horse.

The newcomer on the government R&D scene is the objective I call societal well-being, in which it is not at all clear that any notion of technological supremacy is an asset. There are people who believe it is a debit. There seems to be a searching for an R&D role. We have tried an enormous amount of experimentation looking for technological fixes to social problems. We are not by any means in agreement that there are such fixes or if they exist, that they are very good. This is the arena in which new funding of R&D has grown most rapidly under federal aegis. To go back to my general rule about who will spend money if you make it available, one can observe a spillover of technology and technical people from the sectors surrounding national security into the sector I loosely identify as societal well-being.

Let us look at the individual firm, not the industry of which it is a part, but the isolated firm. What is it interested in? (1) Survival, which in a sense is the analog of national security; (2) Growth, at least a sustaining and growing of profits and generation of cash, which is the analog of economic well-being, and (3) Strategic positioning of the company in a credible way for the future, which is completely separate from any government objective. Now in those three company-limited objectives--survival, growth, and strategic positioning--R&D often plays a central role. The technological inventory and assets of a company and the extent of its technological supremacy with respect to its identified competition often are measures of the freedom of action which that company has to control its own future as well as the opportunity it has to go in new directions without being troubled or bothered by would-be competitors. R&D is simply the process of acquiring those technological assets, nothing more, nothing less. Nobody makes money, nobody survives, nobody grows because he performs R&D. It is only success translated into tangible results--profitability and cash generation--which within the very limited context of the firm puts value on investments in research and development.

Now let's look at the way the company behaves, and let's look at it in two scenarios: in the context of a growing economy and in the context of a non-growing or slowly growing economy.

How does a company behave in a growing economy? If the company is also growing, if new demand appears, if because of prior technical investments new opportunities have been identified that can be exploited, then the successful company, the one with technological strength, will be aggressively seeking to grab market share. It will see its future in terms of the conventional flattening growth curve in an industry, or industry segment, as being best conducted by seizing an adequately large sector of the available market. It behaves to secure that market over time so that when the growth slows down and the demand begins to taper off, it finds itself locked into an attractive, potentially defensible position. I said that it seizes market share. I use that shorthand as a proxy for its actions to reduce cost and to produce future profits. Typically, the guidelines for decision making will be to maximize the total cash inflow taking into account the company's discount rate. And while industries may be the same and products may be similar, companies are different. The discount rates for Company A and Company B which seem to look alike from the outside may or may not be the same. It depends on the management, the way the company has grown up, the way in which it is structured, and its perception of its own future.

In a growing economy the company wants to scale up its size as quickly as possible, consistent with its ability to generate cash. This means in a technological industry that there will be a high premium on new businesses to grow in new directions, on new products to increment existing positions, and on new processes to reduce current costs, each one of which added together means share, position, long-term future. In addition, the company may also use research and development to find and exploit technology for its own benefit; and often, just because of the nature of technological investments, the spinoffs, or overflow, turn out to be even more beneficial than anyone had imagined when the initial effort was mounted.

We had such a technologically-inspired growth period between the end of World War II and the mid-sixties. The United States was trying to catch up for ten years of great slowness during the Depression, for five years of intense, unidirectional devotion of the economy during the war, and for the opportunity created by the vacuum caused by the troubles of other people after World War II. It seemed in that period to be the general rule that more R&D was good, in and of itself. But in reality, the circumstances of the individual firm in a rapidly growing economy were broadly applicable across the whole society, and it was generally the rule, rather than the exception, that every firm experienced this scenario. And so as a preferred offensive investment rather than buying another company, rather than just replicating plants that already existed, either here or abroad, companies did choose and should choose under those conditions to invest in R&D.

That brings me to another point. R&D is a discretionary investment seen from the point of view of the firm. But from the point of view of the national economy, R&D as a whole is not a discretionary investment; it is a defensive investment. We often have seen concern expressed recently within the federal government that companies don't seem to invest enough money in R&D. It is said that companies are too staid in their ways, too conservative in their views, too unwilling to take risks.

Let us look next at the no-growth scenario. There is no opportunity for an aggressive firm to seize market share incrementally, except by cutting price. There isn't a new market and if any firm other than the lowest cost manufacturer tries to grab share by price cutting, he does so at great peril to himself. Somebody else can always come along who is making more money, or at least losing less, at the new low price because of lower costs. Other than to seize an opportunity to grow in an expanding situation, or to drive somebody out of business, price reduction is suicidal except for the most efficient company in the industry. The only way in which you can get technological growth is by invasion of an industry, either from the outside with a revolutionary idea or by somebody in the industry playing "you bet your company," which is suicide more often than homicide. When there is a great upheaval in a well-established industry, it virtually always occurs from the outside. The invader is someone who brings new technology and applies it to an old industry. He does so because the established participants don't see it. He recognizes the relationship between suicide and price cutting below cost and grabs the market share that isn't there.

Now from the point of view of the government or of society as a whole, we are all better off for having old industries invaded and destroyed by new technology. We would be even better off to have old industries renew themselves, but they would have to do so by what from the firm's point of view seems like excessive investments in technology.

In examining the relationship between the economy and technology, we eventually focus on changes in productivity. From the close of World War II until the mid-1960s, the annual average productivity increase for each worker in manufacturing industries was about 4.1 percent per year. From the mid-1960s to the present, that number has been only 1.6 percent per year. What happened in the mid-60s and why are there two so different rates? The productivity change rate, to the extent that technology is involved, does not distinguish between the grinding improvement and cost reduction which take place in completely mature industries in a slow-growing economy, and the radical innovative improvements that take place in periods of rapid growth, change, and intervention by new technology in old industry. The twenty-year run from 1945 to 1965 really had a lot of that intervention in it as compared to the last ten years.

The question that Jordan Baruch posed concerning the dynamics of innovation, and what if anything can be done to promote the rate and quality of innovation is the right kind of question to ask. In my growth scenario the firm has strong incentive to build new capacity. In the no-growth scenario, the company has enormous incentive only to debottleneck, and to provide at most small increments of new capacity. In the two kinds of economic climate the government interest in broad technology and technology strength, if not supremacy, is legitimate. But the firm tends to act in its own best interests, which when the economy is not strong, fly in the face of our collective interest.

What are the problems that lead to these slow growth or no growth environments? What causes companies to shorten the horizon of their R&D by narrowing the range to which they apply? What causes companies to focus on their present businesses and not to take the kinds of risks which if successful could upset industries and technologies, and result in dramatic innovation? There are three identifiable current problems where the government plays an important role:

(1) Inflation. The rapid rise in interest rates, which reflect inflation expectations, push R&D decisions toward a shorter time frame in which to require success and payoff, thereby narrowing the frontiers on which to gamble with technological investments.

(2) Deteriorating terms of trade. These create uncertainties with respect to the various ways in which a company can choose to position itself. We have focused in the last dozen years on the multinational firm and its impact on countries outside the United States. We have failed to focus on the fact that the multinationals are constrained in the way they operate either by legislation in various countries or by their perception of the economic climate. To the extent that the operations of these companies become better defined and better contained, if I can use that word, in other countries, virtually all of the containment is achieved at the expense of the United States economy.

(3) Increasing federal intervention into the details of business. There has been an enormous amount of discussion about the role of the government in regulating business. I would simply point out that in terms of the support and encouragement of technology, it is not merely regulation that is involved. The tax laws also have a tremendous impact on the point of view of the innovator, the entrepreneur, and risk-taking companies.

And so, I come to the bottom line which is, I am sad to report, not a very cheerful one. The slowdown in technological investment in this country is not to our general advantage and yet it is driven by the same set of forces that are threatening to stagnate our whole system. We have to learn how to control our spending better and how to get a grip on inflation rates so that they are sufficiently low. I do not mean zero by any means, but sufficiently low and sufficiently stable rates that they become predictable, because predictability is the important factor.

Finally, I think that we have to examine carefully every government action, taken in the name of improved economy and improved regulation, and see the extent to which it reduces instead of increases competition. It is the gleam in the eye of the aggressive business executive to gain advantage that he can turn into incremental profits, incremental security, and an incrementally stronger grip on the future that causes him to invest more than the average competitor in technology. And he will not do that, unless and until, he believes he can see the future well enough to be willing to gamble at the high discount rate required of technological investment. Just remember, when you go to the bank and borrow funds at 9 percent or 9.5 percent for very long periods of time, that seems like a high interest rate to pay compared to the long-term interest rates of 3.5, 4, 4.5 and 5 percent which we have experienced in this country on long-term debts. But the real problem faced by the boss of the firm is that the cost to him of the equity he has in very limited supply is not 9 percent (4.5 percent after taxes), but rather 16 percent or 18 percent or perhaps 25 percent, depending on his company. He always has that problem to deal with. Thus, adding a few percentage points to his discount rate because of inflation may push him beyond the point where he can invest in new technology; or at least can push him to the level where he is going to reduce risk taking until he sees that there are better days ahead.

Prepared Presentation

George S. Lockwood

Founder & President
Monterey Abalone Farms

When Bill Carey asked that I participate in this morning's session he requested that I discuss the constraints to innovation that we have experienced as a small company pioneering a new technology. In fulfilling his request, I hope to define the serious consequences for our country of the failure of our government policy-makers to understand the critical role of the entrepreneurial function in the process of putting scientific knowledge to beneficial economic use. In addition, I will share with you my observation that we are a nation of people who have developed a great aversion to risk, who are asking government at all levels to respond with increasing regulation and greater involvement in our private activities.

Both of these factors--ignoring the critical entrepreneurial function in economic growth and our culture's growing aversion to risk--are resulting in serious constraints to innovation. Consequently, we are experiencing long-term economic stagnation. Much of the scientific knowledge we are developing is not being used, and there has emerged, in my mind, a serious question of why our government should continue to finance the development of science if government is simultaneously going to create major structural constraints preventing its useful application?

In describing to you how I have reached these conclusions, I would first like to tell you about: (1) my company, Monterey Abalone Farms; (2) the infant aquaculture industry; (3) the existing small business innovative climate in our country; and, (4) the historic and current need for the innovative process to properly function. In doing this, I will point out the apparent reasons for the economic stagnation our country is experiencing as well as what I believe to be the basic, underlying causes.

Monterey Abalone Farms was founded in 1972 to domesticate the abalone. Abalone is a large snail of commercial importance in the western U.S. and in the Far East, accounting for $200 million in world commerce annually. In Japan, abalone is served raw in thin slices as sushi. In other areas of the Orient, it is sliced and cooked in sauces with vegetables. In the U.S. we pound sliced abalone into thin steaks that are fried in egg batter, and the English, of course, boil it in a stew.

In the early 1970s, we saw significant changes occurring in the supply and demand for abalone. Due to rising standards of living, a strong demand had developed (and was continuing to develop) for this premium restaurant item in world markets. Simultaneous with this increase in demand was a substantial decline in the availability of abalone from natural resources. As a result, prices for abalone products were increasing, motivating us to explore the possibility of growing abalone under controlled conditions. I must emphasize that the principal incentive for us to pioneer abalone culture was to build a viable and profitable business. In economic terms, we undertook the "entrepreneurial function" to combine labor, capital and scientific knowledge to develop a profitable product for consumption.

In response to this economic opportunity we founded our company in 1972 to undertake the biological and economic research to determine the feasibility of such a venture and to develop a laboratory technology. Ten individuals jointly invested $250,000 of "seed" capital for this risky undertaking. None of us were particularly wealthy individuals, and this initial high-risk capitalization came from our personal flow of savings. During the next two years, we successfully developed a laboratory technology for spawning abalone, hatching their eggs, growing their larvae, producing their food, and growing the young animals into marketable adults.

In 1974 we began to scale-up our operations and increased our investment by an additional $1,000,000. As before, this investment was supplied by individuals willing to risk part of their personal savings on this promising yet unproven venture. Although the profit potential was attractive, professional sources of venture capital were not interested in such a long-term project. Our company was entirely privately financed by a small group of local people with confidence in me and in our product.

During the next three years, we experienced major problems in scaling-up our laboratory procedures. However, in 1977 we began limited production after further experimentation, frustration, and hard work. I must emphasize the word "limited"--the reason for this emphasis will be apparent later.

In developing this production technology, we directly utilized ten basic sciences and five disciplines in engineering. Included are molluscan reproductive physiology, marine bacteriology, marine protozoology, organic and inorganic seawater chemistry, phycology, pharmacology and toxicology, nutrition and genetics; and civil, mechanical, electrical, electronic, and chemical engineering. The fields of poultry nutrition, poultry medicine and poultry husbandry also made important contributions. Many of these areas of science are basic and their development has been supported by NSF, NIH, and the USDA for the purpose of increasing knowledge without specific economic justifications. In contrast, our technology has not utilized any of the applied development work so popular in marine sciences today. Such heavy applied development programs have been of no value to us.

Earlier I stated that our abalone culturing technology was in limited operation. To understand "limited," let me next describe the status of the aquaculture industry.

"Aquaculture" is a word that you will hear with increasing frequency in the future. It is simply the growing of plants and animals in fresh, brackish or marine waters under controlled conditions. Aquaculture is emerging as part of the natural evolutionary process to use science to produce goods in response to favorable market demand and production economics when they develop. I am convinced that if aquaculture could develop untrammeled, it would make substantial contributions to the elimination of the world food shortage with the production of large quantities of low cost food.

In the United States, several segments of the aquaculture industry have already developed. Almost all of our catfish, trout, and eels are produced in aquaculture, as are substantial quantities of oysters, clams and freshwater crayfish. I would estimate that aquaculture contributes at least $250 million to the U.S. economy annually.

In addition to this more mature sector of the aquaculture industry that emerged prior to the early 1970s, a number of species are at the take-off stage and could be in large-scale production within the next five years. They include abalone, scallop, shrimp and salmon. A number of other species such as lobster, crab, conch and mussel also hold promise for large-scale production sometime in the future.

Because of the developing worldwide interest in aquaculture as a potential major food source, the U.S. Department of Commerce approximately eighteen months ago commissioned the National Academy of Sciences to study the prospects and constraints to aquaculture development in the U.S.[1] The private sector was urged to contribute to this study and our firm prepared a detailed report, entitled "An Analysis of Constraints and Stimulants to Aquaculture Development in the United States."[2] Our study reached the following conclusions:

1. Aquaculture's development is not being constrained by a lack of scientific knowledge. An adequate scientific base exists for the development of many species for high-intensity, large-scale culturing. This does not mean that all technical problems are solved, but a substantial scientific base has already been developed in the sciences of marine biology, oceanography, animal husbandry, etc., to form the foundation upon which production technologies for many species can be developed.

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[1] National Academy of Sciences, Aquaculture in the United States, Constraints and Opportunities (A report by the Committee on Aquaculture, National Research Council, available from: Printing and Publishing Office, National Academy of Sciences, 2101 Constitution Avenue, Washington, D.C. 20418, Library of Congress Catalog Card No. 78-52270, 1978).

[2] Lockwood, George S., An Analysis of Constraints and Stimulants to Aquaculture Development in the United States (Monterey Abalone Farms, 300 Cannery Row, Monterey, California 93940, 1977)

2. A major constraint to the development of aquaculture is massive and diverse government regulation and involvement in decision-making. For instance, there are forty-two government agencies at the federal, state, regional, county and municipal levels which regulate our new company in one way or another.

3. The principal constraint to the development of aquaculture in the United States is an array of federal policy decisions that are preventing the formation of risk-capital and blocking its flow into all forms of innovative small businesses.

Let me first describe to you the regulatory environment in which our new industry must emerge and operate.

Some forty-two federal, state, regional, county and municipal government agencies enter directly into our company's decision-making process. At least fifty percent (and closer to seventy percent) of my time is spent dealing with government instead of applying this time as the chief scientist, chief engineer, chief financial officer and general manager of our company. A great deal more of my emotional and creative energy is spent with government than these figures reflect.

This tremendous amount of government regulation has evolved because we Americans expect a great deal from our government. For instance, we ask government to:

- protect our environment
- protect the quality of food we eat
- protect wildlife
- protect employee safety and welfare
- protect investors against security fraud
- protect navigable waterways
- protect land uses (particularly coastal lands).

In addition, we ask government to use our tax structure for the distribution of wealth and to encourage savings for retirement. Each of these areas of government involvement directly impacts upon aquaculture.

It is my opinion that most of these areas of protection and public policies are justified in themselves. Most of us don't want to live in a contaminated environment, nor eat impure foods, nor see our wildlife disappear, nor be employed in unsafe places, nor to be the victims of security fraud, nor to see our navigable waterways destroyed by dangerous encroachments, nor to see our land (notably coastal lands) become overdeveloped. As a result of our desires, our government has responded with well intended legislation and has constructed efficient, well-managed agencies to fulfill our expectations.

However, when it is all added together this broad spectrum of government protection places an insurmountable burden on those of us attempting to pioneer new technologies, particularly those of us who must use small companies to do this pioneering.

I cannot possibly discuss all forty-two agencies at this time. Let me relate a few examples of how the quest for protection has impacted upon my company:

Government Activities That Cause Uncertainty--Because of our desire to eat pure food, the Food and Drug Administration was created to administer laws and regulations for growing or producing food. Rules for such production are changing almost daily, and the technology for detecting the most minute parts per trillion of some contaminating compounds from municipal and industrial wastes is evolving very rapidly. As a result, all sorts of microscopic levels of contamination are being discovered in a wide range of foods. It is my belief that a substantial portion of the East Coast shellfish industry will be prevented from selling its products in the next decade as a result of small levels of contaminants concentrated in the tissues of these animals.

Such uncertainty over future regulations compounds the risks of pioneering new technologies such as ours, particularly where large investments in crops must be carried over several years.

Rules Designed to Apply to Others--In the area of environmental protection, it is now illegal for fish to go potty in the water. All levels of government, from municipal to federal, have regulations affecting discharges of water from "point sources." The question of which precise regulation applies is still confusing, and aquaculture operations probably will be treated the same as sewage treatment plants. Enormous amounts of time and creative energy are going to be necessary for our industry to achieve reasonable regulations under which we can survive.

This type of regulation requires time, capital and creative energy to assure that satisfactory modifications are made to existing rules and laws that have been designed to apply to others.

The Initial Rule-Making Process--In the area of employee protection, the involvement of OSHA in the affairs of business is notorious. The Assistant Chief of the California OSHA Program recently stated that there are more than 28,000 rules of his agency that are enforced upon California businesses. Having been a victim of an ill-founded OSHA inspection, and having to have spent upwards of 1,000 hours of my time litigating appeals and variances (OSHA was overruled in seventy percent of their citations) in order to save valuable start-up capital, I can personally testify to the oppressiveness of this particular agency.

In addition to rules applied to all businesses, OSHA now has a new area of regulation that will have a substantial impact on the future of our industry. This new area is diving.

Approximately two years ago, federal OSHA became concerned about the safety of men diving to depths as great as 1,000 feet with elaborate equipment and breathing gas mixtures in the Gulf of Mexico from off-shore oil drilling ships and platforms. As a result, OSHA held a public hearing in New Orleans and established an elaborate array of diving standards that would apply to any employer whose employees dive under water. In our operations, we rely upon shallow water scuba diving for scientific research observations, the collection of breedstock, and maintaining plastic pipelines that run into the ocean. In no case do we dive deeper than forty feet. Without this diving capability we could never have started our business, nor could we continue to operate, nor could we continue to advance our technolgoy.

In all respects our type of diving is substantially different from off-shore oil drilling diving for which the OSHA standards are designed. Nevertheless, they apply to us. Or, should I say they did apply to us until the California aquaculture industry and research diving community obtained a one-year exemption to prove that our operations were different. At this time, this group, under the direction of California OSHA, is preparing "reasonable" standards. The time involved in this matter has put a significant strain on my company.

This is just one example of how the energy of creative people in innovative new technologies can be drained by the regulatory rule-making process--yet our survival is dependent upon being directly involved in such rule-making when we are aware that it is occurring.

Absolute Prohibitions--Another significant area of regulation concerns our California Coastal Zone. Several years ago, California voters decided to prevent our coastlines from being developed on a wall-to-wall, Miami Beach basis. As a result, our state government is requiring all sixty-eight zoning jurisdictions within the coastal zone to develop precise plans for all lands within their jurisdiction. Because aquaculture must have access to clean water, our California Aquaculture Association asked all sixty-eight zoning jurisdictions to allow aquaculture access to areas of clean water in the ocean. They responded by assuring us that they were considering aquaculture's needs by making our use allowable within areas zoned "industrial." We then informed them that the water quality in most industrial areas of our state was incompatible with growing of fish and shellfish (particularly in view of changing FDA standards relative to concentrations of contaminants in seafood), and we therefore requested access to rural areas where water quality would be substantially superior. The zoning jurisdiction then responded "the oil industry is requesting the same favorable treatment--how are you different?"

Again, the burden of proof was placed upon the shoulders of our struggling industry. There is no way that we can appear before sixty-eight zoning jurisdictions to plead our case. In this situation of land use regulation, I am convinced that our new industry, with its new technology, will be precluded from the quality of water we need in order to grow our animals successfully. Because of the overbearing nature of this situation, I consider this type of government involvement to be an absolute constraint.

I could go on and on relating similar situations with most of the forty-two agencies. In some cases I believe it is the intention of our lawmakers to protect us from legitimate problems and address real social needs. In other cases it is to fulfill the wants and desires of the voters that may not represent real problems or needs. In responding to these real needs or voter wants, our government has put together good and efficient organizations with well-meaning people to administer these laws and policies. These good, well-meaning people in their efficient organizations then become our adversaries. When in doubt, their choice is to err on the safe side, that is, to protect (no matter what the consequences) whatever the regulators are charged to protect. In almost all cases there is no consideration of the costs of regulation upon the entity being regulated; indeed, the costs to you are rarely important to them. As a result, many of these government programs are truly oppressive, and I am not using the word "oppressive" carelessly or emotionally. Our society is paying an enormous price for these programs in terms of stymied creativity and initiative, particularly as they pertain to small innovative businesses.

I hope that my comments about these examples are not perceived as being from "just another complaining businessman." Nor is the issue I am raising one of equity or fairness to the little guy. The problem is much more far reaching, and it has profound ramifications affecting our nation's economic health.

Not only is there the direct cost of compliance with this regulatory octopus that innovators must absorb into their initial capitalizations, but there are large hidden costs requiring the innovator's direct participation that are significantly blocking his creative processes.

In reviewing the status of aquaculture and our attempt to emerge as a new industry, several conclusions can be drawn that may apply to new technologies yet to be developed:

1. Uncoordinated, widespread and intense government regulation and involvement in the aquaculture industry is a major constraint. It is unrealistic to expect fifty to seventy percent of an innovator's time to be spent on government relations. The alternative of "going underground" is an invitation to disaster, yet some firms in our new industry are deliberately ignoring government and maintaining the lowest possible profile, hoping not to get caught.

2. Although our situation may sound extreme due to the "high regulatory profile" possessed by aquaculture, I believe our experiences probably indicate the governmental environment in which many, if not most, new technologies must develop and operate in the future. Aquaculture is simply the forerunner of new technologies being pioneered in the new regulatory environment.

3. The make-up of our future economy will consist to a large extent of only a few new industries that are able to emerge because they have a low government regulatory profile.

4. The only innovators who will succeed in putting science into profitable production are ones who have the skills to map and navigate successfully the government regulatory maze. This will probably preclude many potential innovators who know their fields of science and who could cope with normal business problems, but do not have the knowledge, skills and patience to deal with such heavy and diverse government involvement.

5. Free entry is a basic principle of economic growth. Our present regulatory environment is constraining "free entry" in aquaculture, as well as in other needed new technologies.

If we are to achieve economic benefits from the profitable utilization of science, someone must put it to work. That someone must be free to create, yet the plethora of well intended involvements of government in business affairs--particularly the affairs of innovative small businesses--is blocking the creative process. This blockage has virtually halted small business innovation in America.

Let us next look at how federal policies are precluding the availability of capital for innovative small businesses.

Most small business innovators require outside sources of capital to launch their businesses. Initial "seed" capital requirements are greater today than ever before due to inflation and the high costs of complying with government involvement. Unfortunately, however, the availability of risk-capital of all kinds--seed, start-up, and expansion--has all but disappeared since 1970 due to an array of federal policy decisions.

In my opinion there is no greater constraint to technological innovation in America than this recently developed lack of investment capital for small innovative businesses.

This decline can be readily seen from the following table[3] that shows the capital acquired by firms with less than $5 million in net worth from public offerings since 1969.

Year	Number of Offerings	Total Amount (Millions)
1969	548	$1,457.7
1970	209	383.7
1971	224	551.5
1972	418	918.2
1973	69	137.5
1974	8	13.1
1975	4	16.2

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[3] U.S. Small Business Administration, Report of the SBA Task Force on Venture and Equity Capital for Small Business (available from: SBA, 1441 L Street, N.W., Washington, D.C. 20416, January 1977).

The catastrophic disappearance in capital available to small businesses is clearly apparent, yet during the same period money raised for all corporations in the public securities market increased from $28 billion in 1972 to over $41 billion in 1975, or almost fifty percent.

This disastrous trend is also true for other sources of small business financing, including professionally managed venture capital pools and high-risk investments by individuals.

Let us look at some of the reasons for this decline in small business financing.

Savings Are Now Flowing Into Large Pension Funds--The principal source of investment capital in the U.S. is the stream of savings flowing from the American public. Savings is defined as the difference between personal disposable income and what we consume or spend. As these savings accumulate, millions of Americans in the past have had to decide how to invest them. Some have gone into savings accounts, some into homes and other real estate, some into marketable securities of local and federal governments and large corporations, and, until recently, a small but significant amount has gone into new small ventures to pioneer new technologies.

This latter portion of the flow of savings into seed and start-up capital has been the principal source of financing small innovative businesses in the past, and it has been critical and essential to technological innovation and economic growth in our country. Unfortunately, this flow of capital has now ceased.

This cessation of the flow of individual savings into innovative small businesses is the result of federal policies initiated in the late 1960s and early 1970s to encourage our populace to save for retirement security. At that time Congress enacted tax incentives (through IRA and Keogh plans) for individuals to place their savings into large, centralized professionally managed pension funds. Congress then passed ERISA legislation in 1973 to protect these savings and required such funds to be "prudently" invested in mature securities.

Before the enactment of IRA, Keogh and ERISA, hundreds of thousands of individual savers such as doctors, lawyers, farmers, small businessmen, etc. in the towns and cities throughout America had a broad range of investment opportunities available at their discretion, including, in some cases, participation in worthy small innovative ventures in their local communities. Since IRA and Keogh, tax incentives encourage these individuals to send their savings to a few large pension funds located in major financial centers that then "prudently" invest these savings in stocks and bonds of mature, secure, well-established companies or into government financial instruments. The investment decision-making has shifted from many local savers to a few centralized fund managers. These fund managers are not only unable by law but are disinterested in investing in small innovative businesses scattered around the country that are pioneering new technologies.

The evil in the IRA, Keogh, and ERISA package is twofold:

1. It has diverted the flow of savings that previously went into high-risk innovative investments into markets for mature, secure investments, and
2. It has shifted investment decision-making from hundreds of thousands of people on the local scene to a few centralized "professionals."

The net result is that Congress has inadvertently eliminated seed and start-up capital investments in innovative small businesses in response to society's demand for greater retirement security.

The Centralization of Investment Decision-Making--In the case of my company, I can say with absolute certainty that the local aspect of our first "seed" capital and of our second "start-up" capital acquisitions was of paramount importance. Investors at each stage knew me well and knew our product opportunities well. In fact, some of them were essential driving forces in getting me to undertake this venture and to continue it at times of frustration and failure. I am sure that this is the situation in thousands of other cases of successful start-up ventures when deciding whether or not to begin or to continue pioneering new fields.

Conversely, the professional managers of "venture" capital pools have been of no help to us. Although our potential economic returns were attractive to them, our project was either too risky or had a time period to first profitability excessively long for their sophisticated investment criteria. Without the local investment decision, we would have never started.

This shift in small business investment decision-making from local investors who are patient and possess a greater depth of human understanding and who invest because they have faith in the entrepreneur and his project, to professional, sophisticated financial managers is, in my opinion, another substantial deterrent to seed capital investment in innovative ventures. The professionals do not take risks to initiate many worthy ventures, nor do they have the psychological make-up and patience to nuture the entrepreneur and his small business through the inevitable hard times.

This shift in seed capital and start-up investment decision-making is another factor contributing to the decline in small business financing. It, too, has resulted from our society's demands of government for greater security for our retirement investments.

Our Desire to Prevent Security Fraud--Over the years our governments at the state and federal levels have moved with increasing intensity to protect investors from security fraud. As a result we have a very active group of lawyers at the Securities and Exchange Commission, and in various state commissions, policing investment offerings, both public and private. The net effect of this protection is that a company such as mine desiring to raise upwards of $500,000 in new capital from public markets is faced with an outlay before the offering of $200,000 in legal, accounting and printing costs to obtain the necessary SEC registration.

Our security regulators have done such a good job of protecting us from security fraud that they have completely slammed the door to public financing for many honest and worthy innovative businesses.

And There Are Other Reasons--Although capital gains taxation is a controversial subject in Washington these days, there is no doubt in my mind that the increase in capital gains taxation that has occurred since 1969 has greatly diminished investor interest in small high-risk ventures such as ours.

Our unduly complex tax laws are a major determinant of the flow of savings into investments, and our present tax structure substantially hinders investment in high-risk, small innovative businesses.

All of this adds up to a major disaster to all forms of innovative new businesses. Again, well-meaning government policies have had major, unpredicted, secondary effects. These secondary effects have virtually eliminated investment capital from innovation and are a major factor in the inability of our economy to utilize the discoveries of science to provide economic growth.

The main thrust of my presentation so far has concerned the consequences of governmental actions on small innovative businesses. It might be helpful then, to take a look at the importance of the individual innovator and his small business.

In our American economy much of the application of science to accomplish technological innovation occurs in large corporations. Although research policies in American industry are changing towards low-risk research investments (a trend that I believe is adverse to the continued development of our country), large companies undoubtedly will continue to make major technological advancements. However, an examination of American business history from the late 1700s through 1970[4] clearly shows that a major, if not the major, source of technological advancement has resulted from the work of individual investors and individual entrepreneurs working independently of our large industrial corporations. This is particularly true when radically new concepts have been introduced.

In our early history we had Eli Whitney in 1793 with his cotton gin and Robert Fulton with the steamboat in the 1840s. These two innovations had an enormous impact on young America. Then came the railroads, and next we had Morse, Bell and Marconi in the field of communications whose contributions greatly accelerated the growth of our economy. Similarly, the Wright Brothers, McCormack, Edison, Westinghouse, Ford and DeForest, using science and engineering, made introductions that laid the foundation for further economic advancements. This is obviously only a partial list. All of these innovators were small guys.

The same trend continues after World War II. We are all familiar with the success stories of Edwin Land at Polaroid and the Watsons at IBM. During the 1960s we saw the emergence of many companies such as Xerox, Digital Equipment

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[4] An excellent study of American business history that, amongst other things discusses technological change, is The Visible Hand--The Managerial Revolution in American Business, Alfred D. Chandler, Jr. (Belknap Press of Harvard University Press, Cambridge, Massachusetts 02139, 1978).

Corporation and Hewlett-Packard, each beginning as individual small guys with their small companies who were able to use science to innovate. In addition to these better known names, there were thousands of small, less known, high-technology companies spawned during the 50s and 60s and which have created real growth to our economy and have increased the quantity and quality of employment.

Since 1970 the process of formation for new high-technology companies has virtually ceased. Yet it is clear to me that we cannot rely solely upon big corporations to make all of our future advances. What about the mavericks? What about whole new industries? Or radical innovations necessary to shake existing industries into lower cost production and expanded markets?

To a large extent the pioneering of entirely new industries (in contrast to expanding existing technologies or making them more efficient) is largely up to individuals in new businesses. This need is more prevalent today than pre-1970, since there is a well-established trend by large companies to apply their reduced research efforts to the improvement of existing products in existing markets where the risks are easily defined, and where the pay-off of investment is a shorter distance into the future. This phenomenon of large corporation hesitancy to enter new fields clearly exists in aquaculture where, with few exceptions, large companies are unwilling to pioneer this new technology but are, instead, waiting for individuals and their small businesses to pioneer their technologies and establish profitability before the large companies acquire the small pioneers.

The role of small innovative businesses in stimulating economic growth also can be seen from two recent independent studies. The first, by the MIT Development Foundation in 1976[5] shows compounded average annual growth from 1969 to 1974 for the following three groups of companies:

	Sales	Jobs
Mature Companies	11.4%	0.6%
Innovative Companies	13.2%	4.3%
Young High-Technology Companies	42.5%	40.7%

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[5] Flender, John O., and Morse, Richard S., The Role of New Technical Enterprises in the U.S. Economy (MIT Development Foundation, Inc., 501 Memorial Drive, Cambridge, Massachusetts 02139, 1978).

In this study, mature companies were Bethlehem Steel, DuPont, General Electric, General Foods, International Paper, and Proctor & Gamble. Innovative Companies were Polaroid, 3M, IBM, Xerox, and Texas Instruments. Young high-technology companies included Data General, National Semiconductor, Compugraphics, Digital Equipment, and Marion Laboratories.

The MIT report states: "It is worth noting that during the five-year period the six mature companies with combined sales of $36 billion in 1974 experienced a net gain of only 25,000 jobs, whereas the five young high-technology companies with combined sales of only $857 million had a net increase in employment of almost 35,000 jobs. The five innovative companies with combined sales of $21 billion during the same period created 106,000 net jobs."

Similar conclusions emerged from a study of 269 electronic firms by the American Electronic Association. This past February, Dr. Edwin V. Zschau of the AEA presented the conclusions of that study to the Senate Select Committee on Small Business. The report showed the following growth of employment for new established firms as contrasted to more mature companies:

Years Since Founding	Stage of Development	Employment Growth Rates in 1976
20+	Mature	0.5%
10-20	Teenage	17.4%
5-10	Developing	27.4%
1-5	Start-up	57.5%

Dr. Zschau also reported that annual benefits to the economy realized in 1976 for each $100 of equity capital that had been invested in start-up companies founded between 1971 and 1975 were:

• Foreign sales	$70 per year
• Personal income taxes	$15 per year
• Federal corporate taxes	$15 per year
• State and local taxes	$ 5 per year
• Total taxes	$35 per year

This data shows that the benefits of investment in small innovative ventures are large (e.g., a new $35 per year flow in tax revenues for each $100 initial investment) and that this flow of benefits starts soon after the investment. These benefits are large and powerful.

The projections for my company, Monterey Abalone Farms, are similar. During the next five years we anticipate employment growth of fifty percent annually, new foreign exchange earnings in excess of $200 for every $100 invested, and a new annual tax flow in excess of $150 per year for each $100 of new investment.

The need for a climate of favorable small business innovation is clearly apparent from this review of the contributions that have been made by individual entrepreneurs in their small companies to the past and recent economic growth of our country. If we are to continue to enjoy the benefits of innovation, then individual entrepreneurs and their small companies must be able to carry a very large share of the burden of innovation. Therefore, the climate for the formation and nuturing of small innovative businesses is of critical importance. Those government policies that constrain the formation and nuturing of small businesses must be removed.

Let us next look at how these conclusions concerning the role of individual innovation relate to economic theory.

Economists have been telling us for centuries that technological innovation is essential to economic growth. As one examines the writings of the classic, neoclassic and present-day economists, there clearly emerges a predominance of thinking that technological innovation is the principal (or perhaps even sole) stimulus to economic growth. Some economists such as John Stuart Mill[6] in the early 1800s feared that economic growth would someday cease since there were "ultimate boundaries" to technological progress. He believed that everything that could be invented soon would be invented. Others, such as Karl Marx,[7] feared that continued technological development would be used to exploit the working masses by depressing real wages and increasing the margin between the wealth of the capitalists and the poverty of labor, thereby increasing the "misery" of labor. Marx also saw an important role to be played by technological innovation.

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[6] Mill, John Stuart, Principles of Political Economy, Book IV, Ch. VI. (Ashley, ed., London, Longmans, 1909).

[7] Marx, Karl, Capital (3 vols., Chicago, Charles H. Kerr Co., 1926).

As we come into the twentieth century, we find such economists as John Maynard Keynes[8] in the 1930s being concerned, like Mill, that technological innovation would not continue to provide the stimulus that it had earlier. In the 1940s and 1950s we find the profound writings of the Harvard economists Joseph ?. Schumpeter[9] and Summer H. Slichter[10] articulating the need for vigorous technological innovation to prevent economic stagnation. Both Schumpeter and Slichter recognized the absolute essential nature of the entrepreneur as middleman in the process of putting scientific knowledge to work to fill consumption needs. Schumpeter, much to his chagrin, predicted the destruction of capitalism and major economic stagnation as a result of the inhibition of the entrepreneurial process by such external forces as government involvement in private decisions and the imposition upon the entrepreneur of the accomplishment of a wide range of social goals. Schumpeter (in 1942) accurately predicted the present state of economic stagnation with chronic unemployment in America, and its causes. In my opinion, it will take widespread awareness and understanding of Schumpeter's theses by our political leadership before our nation will solve the problems of economic stagnation that we are now experiencing.

Slichter disagreed with that part of Schumpeter's thesis that the stagnation of American business would occur because, amongst other things, Slichter believed that American management with its "energy, diligence, and perseverance" would continue to "make profit promising innovations and thus to discover investment opportunities." About entrepreneurs he said, "The tremendous absorption that many managers have in their jobs springs from the fact that they find their work exciting and challenging--for them the job is fun rather than drudgery" (underline supplied).

Slichter wrote this in the late 1950s. In the context of my experiences twenty years later, I must respectfully disagree. The thirty percent of my time that I am able to spend creatively on abalone culturing is enjoyable and rewarding (although sometimes frustrating and demanding). It is indeed fun. And, it is the fun of pioneering with the realization of accomplishments that has been the driving force to keep me plodding ahead. But there is now fifty percent to seventy percent of my time that must be spent ministering to the affairs of government.

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[8] Keynes, John Maynard, The General Theory of Employment, Interest and Money (New York, Harcourt, Brace & Co., 1936).

[9] Schumpeter, Joseph A., Capitalism, Socialism and Democracy (New York, Harper & Brothers, 1942).

[10] Slichter, Sumner H., Economic Growth in the United States--Its History, Problems and Prospects (Louisiana State University Press, 1961).

Who wants to be an entrepreneur when he knows there are tens of thousands of regulations, many of which the violation is criminal? Take OSHA as an example. No one individual can precisely understand and memorize OSHA's code book of 28,000 regulations. As a result, you are always inadvertently in violation of something, no matter how careful you are! Because you are a small guy without a staff of expert safety engineers and you can't know the code book, you are a sitting duck for zealous OSHA cops--with criminal penalties and fines that can be applied if they feel like it. Add to the 28,000 OSHA regulations the many more enforced by EPA, FDA, IRS, SEC, ERISA, Coastal Zone, Fish and Game, Workmen's Compensation, unemployment boards, Corps of Engineers, planning commissions, Affirmative Action, etc., etc., with their reports, applications, permits, licenses, standards, EISs, variances, rule makings, hearings, burdens of proof, appeals, etc., etc., and rapidly growing enforcement budgets at all levels of government to "make business comply." Is it fun to be on the receiving end of all of this?

In a small business it is the innovator who is the criminal who violates these laws and regulations, and only a few zealous entrepreneurs have "fun" working in such an environment where they are treated by government at best as adversaries, and often as criminals. Couple this with a seemingly continuous flow of litigation expenses against government's to protect your trade secrets that they want to use in competition with you or to make public--"the public must know your technology." Or threats that if you go to the legislative branch of government to stop their encroachments upon your business, they will "put you out of business." Or, "you had better support our legislation or we'll make it rough on you." Or, "if a judge orders my agency to stop--I'll stop--but not until then." What a great environment in which to create!

Slicnter was correct when he said managers of innovation are motivated by the excitement of being creative. But, it is no longer fun, and maybe this explains why innovative entrepreneurs are now an endangered species. Where will our society get good people who are willing to undertake this important function if it is so unpleasant? Our capable business managers will stay with large companies instead--or speculate in real estate--or will seek secure employment as government regulators.

So we have the views of the past economists: technological innovation is essential for economic growth, and the entrepreneur-middleman is the essential link between science and consumption. But will the entrepreneur survive? Schumpeter says no--external social forces will kill him; Slichter says yes--it's fun to be an entrepreneur. From my position at this stage of the game it looks like Schumpeter is correct.

When reviewing contemporary economic thought, Samuelson in his very well-read college textbook, Economics,[11] clearly recognizes the critical role of technological innovation in providing economic growth. Unfortunately, however, Samuelson almost completely ignores the entrepreneurial function. Of 1,000 pages of text he has only three paragraphs describing the entrepreneur. This major omission is clearly reflected in contemporary economic thinking and I believe this omission is a major cause for the economic mess we find ourselves in today.

Present day economists are so concerned about monetary and fiscal matters as they relate to business cycles that they have overlooked the fact that these are only tools to help control economic growth. These economists and government policy makers are ignoring the process by which science is used to produce real economic growth.

During the 1930s, John Maynard Keynes contributed a needed theory of consumption to the body of economic knowledge. Unfortunately, in their pursuit of Keynes' theory, contemporary economists and government planners are placing much too great an emphasis upon consumption, short-term industrial productivity, short-term unemployment, inventory accumulation, expenditures for plant and equipment, consumer moods, and M1 and M2 growth. They are ignoring the principal contributor to long-term economic growth--the development of scientific knowledge and the use of it through technological advances for the creation of consumption by way of the entrepreneurial process. As a result, I believe our country is in a state of long-term depression, a depression in which massive unemployment is being prevented by pumping more and more money into our economy without real growth. The result is chronic inflation.

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[11] Samuelson, Paul A., Economics, 10th Edition (McGraw-Hill Book Company, New York, 1976).

The evil of inflation is going to persist until there is sufficient real growth to offset labor's firm demands for eight percent or more annual wage increases. There will be insufficient real growth in our economy to meet or exceed labor's demands until the entrepreneurial function is unburdened and risk capital is again available from local investors to small innovative businesses, so science can be used again to create those innovations necessary for real economic growth. If I may criticize our contemporary economists, they are preoccupied with the problem of keeping our present stock of men and machines fully employed by our large corporation--and they are not facing the longer cycle problem of real growth through innovation.

Our investment in science will produce minimal returns until the constraints to innovation are recognized and removed and the entrepreneur-middleman is again allowed to put science to work in the private sector on a more or less untrammeled basis. Until then, inflation, high unemployment, limited job opportunities for our youth, and currency erosion will continue to be the product of a stagnated economy in a stagnated society.

So much for economics.

What does all of this mean? The picture is not a good one. The question arises as to why such enormous constraints exist. It seems to me that there are two basic causes underlying all of the symptoms of stagnation that I have been discussing:

1. Our current generation of economists and government policy makers are overlooking the absolute critical role of the entrepreneur, and

2. We are a society of people who have a great aversion to risk.

Can we expect no-risk policies to produce profits and growth? I personally do not believe growth is possible without a higher degree of risk that we are willing to take at this time.

At some point our leadership must ask if zero risk and solving a broad range of voter desires is worth the cost of stopping economic growth. Are the burdens of absolutely pure foods, a pristine environment, "safe" work places, precise land zoning and protection of public viewsheds, the prevention of investment fraud, the encouragement of savings to flow into a few central large trust funds, the establishment of strict fiduciary responsibilities and standards for pension trustees, the comprehensive protection of wildlife, affirmative action, navigation protection in even the small creeks and minuscule estuaries, the distribution of wealth through a complex tax structure, etc., etc., really worth the cost? Each of these areas of social desire may be worthy in their own right, but together are they worth it if our economy and our whole society stagnates? And it must be realized that such stagnation remains a long time. It takes years to put science into profitable production and even longer for the real major innovations to have economic impact.

Some people believe that it is possible to pursue these wide-ranging areas of risk aversion and social concern and not inhibit the entrepreneurial process by modifying our governmental processes to "make it easier for the small guy." These people would somehow make law and rule-making and administration more sensitive to the blocking effects they are having on innovation while still hotly pursuing social and zero-risk objectives in each area of concern. I personally doubt if this can happen. Some degree of social risk-taking is going to be necessary.

The question continuously re-emerges: is our society willing to assume more risk and reduce our expectations of government, thereby relaxing the stranglehold on innovation in order to eliminate the stagnation we are now experiencing with high unemployment, high inflation, and the sinking value of our currency in foreign markets?

This trade-off problem in our priorities probably makes most of us uncomfortable, since we all expect a lot from government. However, I believe that this is a very real question that our nation and our political leadership must address actively and honestly, and soon.

I have covered a lot of ground in this presentation on the constraints to the use of science in the U.S. economy and the consequences. We have examined how basic scientific knowledge that was developed elsewhere for non-economic reasons provided the foundation for a new working technology at Monterey Abalone Farms. We have looked at how a diversity of government regulations being enforced with increasing intensity is preventing the emergence of a badly needed and economically viable aquaculture industry. And we have observed how well-intended federal policy decisions in the early 197[illegible] have almost entirely eliminated investment capital that is required for small business innovators.

We have discussed the important contributions that individual inventors and entrepreneurs and their small innovative businesses have made to our nation from the 1790s through the 1960s, including the impact of high-technology firms founded in the 1960s, on employment, tax revenues, and foreign exchange. We have seen the importance that past economic thinkers have placed upon scientific discovery and its application through the entrepreneurial process to produce economic growth. In contrast, we have seen how contemporary economists have become so occupied with designing solutions to immediate business-cycle problems that they are overlooking the critical importance of innovation and a healthy entrepreneurial environment in order to achieve continuous long-term growth.

It is clear to me that the ignorance of the critical entrepreneurial function by contemporary economists and our government policy-makers, coupled with our society's great aversion to risk in recent years, has led to a depression as serious as those in the past. This time our economy is stagnated due to a major slowdown of technological innovation and we are experiencing long-term inflation, high unemployment, unexciting job opportunities for our youth, and a declining currency in world markets. It will take courage by our political and intellectual leadership to unburden the entrepreneur and accept a greater degree of risk.

I am not alone in these conclusions. In early June Alexander Solzhenitsyn addressed the graduating class at Harvard University on the subject of "The West's Decline in Courage."[12] He said:

> "A decline in courage may be the most striking feature which an outside observer notices in the West in our days."
>
> "Should one point out that from ancient times a decline in courage has been considered to be the beginning of the end?"
>
> "No, I could not recommend your society in its present state . . . ."

It is my understanding of American History that we are a Christian society built by hardworking people of courage who were free to create and were willing to assume risks as the evolution of science produced new opportunities. The advancement of science has continued at a rapid rate, and there are still people who are willing to undertake the challenge of putting science to work to create economic benefits. Unfortunately, the burden of government involvement in our attempts to innovate has become so diverse and so intense that the innovator cannot do his job. The present climate is "discouraging"--in the strictest sense of the word--at a time when we need more courage.

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[12] Solzhenitsyn, Alexander, "The West's Decline in Courage," Address to the graduating class of Harvard University, June 1978.

As a result our stagnated economy and our stagnated culture are maintaining the status quo. To this Solzhenitsyn said, ". . . a status quo is a symptom of a society which has come to the end of its development."

In my mind, Solzhenitsyn is correct in his assessment of contemporary America; we are a society lacking courage that has stopped development. I believe, however, that he may be underestimating the ingenuity of Americans to solve our problems, once they are recognized, even the massive problems now blocking innovation and causing stagnation. In my case, I am confident that my small company, Monterey Abalone Farms, will succeed (probably as a subsidiary of a larger corporation). And I am confident that American ingenuity will demand that government attend to the real needs of the creative process with appropriate risk taking. When this occurs, scientific discovery will again be the beginning point of the innovative processes and America will enjoy all of the benefits of real economic growth.

Discussion

Margery Hoppin remarked that George Lockwood's reliance on basic research in building his aquaculture business is impressive testimony that a strong economy depends on the strength of all of its elements. One of those elements, university research, is in trouble from declining university enrollments, over-regulation, obsolescent equipment, pressure to assume more service operations for the general public, and a cost squeeze caused by government and industry requirements for universities to contribute more of the costs of research and service activities. Strong universities are needed to promote industry's R&D efforts. The basic body of knowledge underlying applied research and development, the leaders in industry, and the fresh young scientists with their imaginative ideas come from universities. Problems caused by university weakness are everyone's, from the AFL-CIO, to Worcester Lab, to United Technologies, so that industries and government should take more aggressive steps to link university researchers with their concerns. "As someone emphasized at last night's session," Hoppin added, "the major gains toward helping our country and the world are made when we work together collectively, so there is a need to share U.S. ideas and technology. Universities contribute a lot to such sharing, with information going not just to industry but to the world body of knowledge."

Hoppin noted that in a previous session, John Sawhill pointed out that there must be an infusion of funds for decentralized grant mechanisms so that universities may help the young investigator in testing his or her ideas quickly; money is needed for obtaining state-of-the-art equipment to replace many of the research methods currently employed. Hoppin added that an entirely new look is needed at the paper burden of nonsensical regulations that have created an emphasis on meaningless cost accounting and expensive defensive documentation with no interest in the product produced, only in the efficiency of the bureaucracy. The result is to drain the energies of scientists and academic leaders. Finally, as suggested by industry people, universities must find ways to stretch their dollars through activities such as equipment sharing programs both within an institution and with surrounding colleges and industries.

One area not covered by any of the speakers or in the AAAS R&D report is the need for industry, government, and universities to find ways to convert defense industries to peaceful purposes. There would be no better way to achieve health in both the U.S. and world economies.

A large portion of this session was devoted to the increasing government regulation of many aspects of industrial and innovative activity. Richard Landry commented that there is an obvious relationship between what Lockwood said in his speech about regulations (and the businessman's uncertainty over them) becoming a great stumbling block for the innovative entrepreneur in the U.S. and the thesis that the rate of U.S. economic growth has decelerated considerably in the 1965-1978 period from that in the immediate postwar period ending in the mid-60s. The numerous impediments to domestic investment stimulate American firms to invest more abroad. Robert Charpie responded with two facts that make it difficult to be decisive about Landry's point. First, except in countries with currencies tied to the German mark, inflation rates are somewhat higher outside the U.S. than inside. The result is economic uncertainty abroad and, if inflation is high enough, political uncertainty, both of which are detrimental to preferential investment offshore. Second, the Western European Common Market is thereby divided into two groups. American investors may only consider one of the parts of the Common Market (say fifty percent) as an alternative market to the U.S. Such markets have not been as attractive in the last ten years as in the ten years before that. American direct investment has continued to go into Western Europe but by no means at the same accelerating rate as in 1955-1965.

Jordan Baruch quipped, "Lockwood's company would seem to have a significant incentive to move to a foreign shore, but if Lockwood thinks he has problems now, wait until he tries to import edible shellfish into the U.S." Lockwood responded that indeed his company is actively considering two joint ventures, one in Australia, and the other in New Zealand. Their governments want to import new technology and they want to develop a strong export earning base (the principal market for the abalone is the Orient) using companies such as Lockwood's. These are two Western governments offering substantial incentives for investment by foreign companies; they are willing to provide up to seventy percent of the capital. The U.S. never talks about creating incentives for technological development or increasing export earnings.

George Eads brought up a curious property of some regulations that stifles innovation--the requirement for companies to study the effects their products will have on users, on others, and on the environment. If the regulations don't kill off a new innovation, the innovator must begin to spend more on activities classified as R&D, including basic research. For example, chemical industries must be interested in the effects of their chemicals on the human body. Such regulation, therefore, will increase expenditures on R&D, but not on innovation.

Markley Roberts noted how Charpie spoke of the purposes of R&D and technological innovation in the order of priority of national security, economic welfare, and societal well-being. The people complaining about regulations and restrictions inhibiting R&D and technical development aren't the Boeings and the Lockheeds and the General Electrics--companies involved in aerospace technology and national defense R&D. It is implicit, therefore, that the problems raised in this session have been those related to the civilian economy.

Roberts added that the tension between technological development and regulation is inevitable. The advocates for technological development, innovation, and R&D, particularly those supporting the role of small business, have legitimate concerns about the effects of regulation. One can sympathize with the litany of problems described by Lockwood. However, we live in a society that involves a lot of people's interest and problems--environmental, safety, health, and social--that are interrelated in a complex way. Efforts to simplify and diminish the inhibiting effects of irrational and unreasonable social regulation should not be carried so far as to throw aside protections of people, society, and our institutions. Regulations do create problems, and businessmen would want life to be simpler. Nevertheless, it is inevitable that in a complex society there will be regulation to attempt to promote the coexistence of diverse interests with a minimal amount of conflict.

Lockwood responded that the growth of the U.S. economy has largely resulted from the exploitation of scientific knowledge, in which both large and small companies have played very important roles. The entrepreneur puts science to work. Lockwood basically agrees with all the areas of regulation: we all want to eat good food, live in a good environment, work in safe places, and prohibit fraudulent financial practices. However, all of these benefits require an enormous cost--the throttling of the use of science in contributing to the economic growth of our country. One result may be the decline from a 4 to 5 percent annual increase in U.S. productivity in the 1950s and early 1960s to a 1.4 percent growth. Is labor willing to exist on a 1.4 percent growth per year in our economy and hold its wage demands to that level? If they don't, the gap will be filled by inflation and a degree of stagnation that will result in more and more inflation. While living with the social demands we ask from our government, we must revitalize the process of the entrepreneur as intermediary between new technological developments and their implementation as products.

Baruch stated that social regulation is a necessity; society has decided to spend effort and resources on reclaiming the environment, on preserving the environment, and on preserving the health and safety of the working force. With government regulation on the increase, present measures of productivity have become obsolete. Part of the decline in productivity talked about by Charpie results from nonsense in the statistics. Society doesn't measure well the achievement of its goals. If a company shows a decline in productivity, one must ask what that company is making besides product X, such as a safer worker or a cleaner environment. There ought to be credit in our national account for the rational expenditure of money on the development of the environment and safety. Steve Plotkin with the EPA carried on Baruch's remarks by suggesting an expansion of the boundaries for the term "productivity." He agreed that the traditional indicators of GNP and productivity don't include how well people are living and are being protected against the effects of pollution. All of the regulations would be struck down if one measured their effects without including factors related to the quality of life. For example, new strip mining regulations can be shown to result in a decline in productivity measured in the traditional way. However, expanding the definition of productivity to include effects on the environment will hopefully show that there is actually an increase in the level of productivity. If an increase in the new "productivity" does not occur from a particular set of regulations, then they are either a failure or not as efficient as they ought to be.

Roberts mentioned that he is at present serving on a productivity statistics review panel headed by Al Rees of Princeton. The panel includes various economists and happily some sociologists. They have been wrestling with the problem of productivity measurement, and Roberts has been fighting with only limited success for a broader definition of social as well as economic output. Ongoing research at the Commerce Department and efforts by those involved in the social indicators movement are aimed at trying to get a better measure of hitherto unquantified social goods. Plotkin's point of obtaining social output not measured by traditional economic indicators is a good one, especially when it comes to cost benefit studies on social regulations. Roberts added, "The Council on Wage and Price Stability, in a shameful past, has gone through analyses on health and safety regulations that are deplorable in ignoring or downgrading human values not easily measured in economic terms."

Thomas Bartlett suggested that the discussants were trying to deal with the confrontation between an efficient economic process and social values by abolishing the confrontation through different definitions of productivity. Instead, one should accept as very much in the common interest a number of social objectives, such as environmental cleaning and environmental protection, and pursue those goals through processes which aren't excessively inhibiting. For example, looking at the processes which support basic research in universities shows that they may be in danger of producing threats to their own purposes; it is clearly unacceptable from a logical point of view, indeed an absurdity, if the processes which fund and support basic research in the universities become such a burden on the investigator that they call into question the research itself. Eads commented that Bartlett's point was a good one. As the former director of the agency criticized by Roberts, the Council on Wage and Price Stability, Eads wanted to put into perspective what the agency was trying to do. Statistics can be manipulated into showing that productivity is booming, but it is critical to keep the distinction between productivity resulting in output salable in the marketplace that can be used to pay higher wages, and productivity creating output that cannot be sold. There is nothing wrong with society deciding it will choose output that can't be sold rather than the other type. The Council on Wage and Price Stability was simply trying to show that there is a real cost that should be known in making this choice. It is unacceptable to redefine the problem out of existence by tricks with the statistics.

Charpie said that the traditional definition of productivity should in principal be modified. However, the important issue is how decision-makers--the people we would like to see making the decisions favoring greater technical investment and risk-taking--behave in the present climate. Such persons are not favoring such investment and they won't be influenced by changing the definitions in the productivity calculations.

Baruch agreed with Charpie in terms of the private sector decision-makers. However, another group, those in the public sector, do refer very heavily to statistics. There are two laws of statistics: (1) Bad statistics will drive out good statistics over time, and (2) Bad statistics result in bad policy. For example, the suggestion was made that since productivity is now growing at an annual rate of 1.4 percent, labor should hold its wage demands to an increase of 1.4 percent. The obvious response is that this increase is not a measure of real productivity and that an exhorbitant proportion of the social cost of reclaiming the environment and protecting the worker would come out of the worker's hide. Policies bad for innovation would be developed through reliance on bad statistics. To illustrate, Baruch mentioned the case of permanent press clothing. All would agree that the development of permanent press clothing was a good innovation. However, it resulted in the release of 1.5 million full-time equivalents into the labor force, increasing the unemployment rate in the U.S. Also, cash transactions that took place with laundries were cut down, decreasing our GNP. The decision that might have been made by public policy-makers based on the statistical evidence of the innovation's negative effects would have led us down a false path. One doesn't want to define the problems out of existence by changing the definition of productivity, but help is needed for rational decision making.

Lockwood introduced the topic of government involvement in new innovative industries. He said that what is not needed is for the Department of Commerce or Agriculture to have an increasingly strong role in his industry. It would be a mistake for industry to ask for a lot of specific legislation to support innovation; this would only compound the problem. What is needed is someone in government to be the advocate of new technologies when they come to FDA, EPA, OSHA, and fish and game commissions. All these agencies don't even know about his new technology but are strangling it. If extensive government involvement in our lives continues, we will need strong advocates for technological innovation. An example of a strong advocacy group is the Small Business Administration. They can go to the bureaucracies and subpoena information and even hold hearings to investigate whether or not a particular small business is being treated fairly.

Sam Raff heads an Institute of Electrical and Electronics Engineers task force concerned with innovation in electrotechnology. It is addressing influences on innovation, R&D, and productivity. In reference to Lockwood's comments he noted that it is unfair that an entrepreneur starting up a new business should be faced with the necessity of interfacing with forty-two different government agencies. Someone in government might be concerned with facilitating these interfaces or at least telling the entrepreneur what they are. Perhaps the government could even identify certain "innovative" industries it wants to help. That would be a rather easy way for aiding them without involving a lot of money and at the same time the government could do what it likes to do best--hire more people to do something.

Grace Burns, from the National Bureau of Standards, questioned Lockwood about changes he thought desirable in government, either in institutional arrangements or operating procedures, beyond creating an awareness among federal agencies of the problems for innovation. Lockwood responded that a basic change in our emphasis on the innovative process is needed. The basis of much of the problem is that a lot of us have studied economics learned from one book by Paul Samuelson. Samuelson is an outstanding economist but in his 1,000 pages he has three paragraphs on the entrepreneural function. If decision-makers were required to read Joseph Schumpeter, who in 1942 wrote probably the most definitive work on the creative process in modern economics, we would have a great revelation, an understanding of the innovative process. Maybe after Schumpeter there should be some reading of Schlichter, who wrote in the late 50s. One must not put down Samuelson, who made a great contribution, but the economics profession is so hung up on monetary and fiscal policies that the basic need for the stimulation of innovation, putting science to work, has been overlooked.

A great worry for Eads is that the entrepreneur who succeeds is the one mastering the governmental process. He noted the entrepreneur's problem of finding venture capital and suggestions that had been made for the government to provide incentives. Eads saw a danger in talking about the extent to which the government should push to interest prospective entrepreneurs in business. The result of the government trying to design the right counter-incentives to offset other incentives, all created by government policy, would only compound problems. If a fund for $100,000,000 to create more venture capital was set up, then one would have to define a "venture capital firm;" there would be regulations on that. In particular one would have to define a "small business venture capital firm" and provide equal access. The result of the government trying to step in and help would be a myriad of regulations.

In reference to a comment by Baruch on sensitizing federal agencies to the importance of innovation, it was mentioned by Grace Burns that five years ago there was a recommendation by Eads that agencies be required to file an innovation impact statement before they promulgated regulations. She noted that Eads has "repented" of this idea. Eads replied that he had indeed done so when given the job of trying to implement another impact statement. He saw the complexities of it and the fact that if the requirement lasts over two years, maybe three at the outside, it ceases to make people think and instead simply employs lawyers. Consideration needs to be given to ways of sensitizing government to basic issues, rather than stimulating endless litigation. Eads stated that he could cite any number of impact statements, each an attempt to sensitize government to an issue, and each of which required for success a reading of its spirit rather than its law. Since we are a nation of laws, the implementation of policy tends to go in that direction of interpretation. He noted that the speakers appeared to be saying that if one wants to encourage innovation in our economy, specific support policies should not be designed. If emphasis were placed on the basic climate instead, it would be a big step forward.

Charles Mosher questioned Lockwood about whether the Sea Grant Program and NOAA (National Oceanic and Atmospheric Administration) are possible advocates for his abalone farm business. Lockwood responded with a criticism of governmental involvement in areas of technology best left to the private sector. Sea Grant was set up ten years ago to provide funding for applied marine research and development to serve as a bridge between oceanographic research at universities and the private sector. Although there have been a few productive Sea Grant projects, the quality of work done has been low in many cases and even counterproductive. Sea Grant administrators have completely failed to understand the entrepreneurial function, the role of taking research and putting it into production in the private sector. In Lockwood's case, government funds went to attempt to duplicate the technology his group had pioneered at private expense because government and university administrators felt that the public must know his technology; yet there were other areas that could have been studied with these funds that would have provided a valuable infrastructure to the aquaculture industry. Congress is aware of this problem and attempts are being made to improve communication between Sea Grant and industry in order to assure that Sea Grant augments rather than competes with private sector efforts.

Charpie noted that Lockwood's remarks are more broadly applicable than to NOAA and abalone aquaculture. A fundamental problem technological industry faces is that it has been fashionable in the last ten years for the government to become involved every time a problem in technical industry appears to be in the government interest. Such involvement has been effective for national security missions but in technical industries it has on the average been nonproductive, in fact, destructive. In the industries Lockwood is talking about, where the entrepreneur is trying to create something new, whatever action the government takes to promote the raising of the general level of technology has the effect of "peanut buttering" the results of the technology across the industry. The effect, assuming there is value in the government action, is to reduce the gap of competence between the least and most efficient members of the industry. Thus, the technological assets of the most competitive member are decreased relative to the industry as a whole. In the more likely case, where the government underwrites an activity without value, money has been wasted. Since the best one can do is to waste money, a focus on such industrial technology is not a sensible government investment.

Baruch quipped that "the next time we have one of these meetings, let's invite two people from government." He said that Charpie's opinion of government involvement in support of technology in industry could be true if government spent its money stupidly. However, there is an area of technology not directly focused on the development of new products and processes, but aimed at the development of basic technologies that firms can use to develop products and processes. Government support in this area is effective; it doesn't decrease the gap of competence between the most and least technologically efficient firms. Rather, it enhances the ability of an industry to analyze markets and develop new products and processes. Government involvement in the area Lockwood was talking about, trying to duplicate the actual production technology, of shellfish, would be an unwarranted intrusion. If on the other hand, government recognizes aquaculture as an important area and invests in the study of protozoa that inhabit bivalves or mollusca or looks at the interaction of seawater chemistry and mollusca (as has been done), then it can develop a set of infratechnologies, that is generic technologies, on which industries can build. An example mentioned previously by Baruch is the attempt by government to help the shoe industry. By examining where the industry is in trouble from foreign competition and what basic technologies are missing, the government is looking for ways to help toolmakers, material suppliers, designers, and manufacturers to revitalize the industry. Charpie's two alternatives, wasting money and unwarrantly intruding, are just two of several alternatives; another is the intelligent expenditure of funds on fundamental technologies. Lockwood concurred with Baruch, saying that in his particular industry an important role can be played by government in developing some of the infrastructure. His technology now in production rests on this kind of research; not on the totally unproductive nuts and bolts development work upon which the government has spent substantial funds. The research policy should be: scientists are best at doing science, not nuts and bolts engineering.

Eads suggested that the problems with and objections to regulation are not so much with the aims of regulation, but with the way the process operates, making the predictability of future regulation impossible. People are saying we must find a way for the regulatory process to function so that situations are not created with which it is impossible for business to deal. For example, non-aerosol fluorocarbon regulations affect a lot of large and small high-technology businesses. Today, because of the uncertainty of future regulation (Will there be regulation on substitutes, complements, etc?) such businesses find it hard to justify to the stockholders putting money into new products. Baruch added that he had been talking to managers in industry and they do say that they could live with regulations if there were a timetable for the future. It is not regulation itself that inhibits innovation, except in the limited case of the small company, and even there such inhibition is secondary. The big factor mentioned by companies is that regulatory uncertainty causes them to discount future earnings and divert their investment.

Steve Merrill, of the Senate Committee on Commerce, Science and Transportation, noted that discussion of the impact of federal government actions on industrial innovation always tends to drift toward the subject of regulation and in turn toward its process rather than substance, perhaps because people feel more comfortable talking about the uncertainty that the process creates for businessmen. Merrill wonders if opportunities exist for reducing uncertainty in regulation. He named three factors contributing to the uncertainty, each of which is generally accepted and presumably will not be changed appreciably:

(1) Science--Continually, there are new discoveries of hazards or of techniques for finding hazards.

(2) Notions of fairness embodied in the Administrative Procedure Act--Implementation of the Act results in more people participating in governmental processes. More steps in each process insure that more people are allowed to have a meaningful voice. However, each additional input creates greater uncertainty about the output.

(3) Politics--Presumably Congress will continue to enact congressional veto provisions to allow reconsideration of regulations people complain about, and the Council of Economic Advisors and the Council on Wage and Price Stability will continue to intervene if, from the Administration's point of view, they see objectionable political implications in some regulations. Only on the margins of these three factors are there opportunities for reducing uncertainty.

Eads suggested that there are opportunities to reduce uncertainty but they go beyond the notion of improving the regulatory process to help innovation. It may help to work around the edges and limit by legislation certain people's ability to intervene, or change the time pattern, but the problem is the ability of government to deal with complex interrelated phenomena. Before there will be much of a change we need to look at government's ability to deal with complex problems involving politics and equity. If we are struck with the present system, then we are stuck with regulation the way it is, and if anything, uncertainty will increase. The uncertainty caused by governmental involvement through regulation is of a different type than the businessman is used to and is supposed to deal with.

Bartlett didn't entirely agree with Eads' analysis. Social change is not a smooth process but is a series of rough jerky movements. In the period at the beginning of this decade and at the end of the last we did some things as a society which were abrupt, introducing significant new variables that we are still trying to grapple with. What we are talking about today are problems of process, not the social purposes that we would not have been talking about ten years ago. We are going to be in a phase concerned with process for a period of time and that begins to reduce the sense of the unpredictability of life. On the level of government policy and programs, one should be relatively optimistic; there will be improvements in the sense of predictability. The real elements of unpredictability are cosmic, not subject to government. Changes in the social values and aspirations individuals share with each other, the impact of which affects our whole society, and significant changes in our society's position relative to other societies are producing significant uncertainty. At that more fundamental level of changes which is beyond our direct control or the control of government action we will see greater instability.

Eads commented that he hoped in the industrial innovation study they will be looking at the larger problems, such as the way business is done today as reflected in regulations. Harm would be done if the study were compartmentalized into asking who is responsible for tax incentives and then proposing changes in tax policy, and who is responsible for antitrust and then proposing changes in antitrust law. Baruch replied that the study hopefully won't be that simplistic. He noted that from Lockwood's viewpoint a major problem is clearly an excess of government regulation. The recommendations to the President won't be simply a set of policies to counteract others; positive actions will be taken. (It should be noted that the regulatory task force will be chaired by the Office of Management and Budget.) A potential area for positive action by government is investment in R&D in an industry controlled by disaggregated firms, where appropriability of the R&D results is a question. The kind of R&D needed by firms which are in that type of industry and which are falling to foreign competition, would be excessive for the individual firm to carry out on its own. One of the options is for government to serve as an aggregating force by supplying part of the capital to permit a combined investment in R&D.

While the industrial innovation study will not be too narrow, it cannot be too broad either. Baruch noted that Eads' ideal of improving the basic climate for innovation, fixing up the economy as it were, is too big a problem to handle. The study would go nowhere if it were mainly concerned with the development of the economy. Baruch mentioned Charpie's point that in a developing economy companies have a different strategy towards innovation than in a static economy, but that there is a chicken and egg problem as to how much the development of the innovative process in industry leads to a growing economy and how much of that growth spurs future innovation and changing strategies. The study will be focused on the process of innovation, not looking at simplistic mechanisms for direct impact on innovation, but looking at those areas of policy that may have an influence on innovation. Regardless of what else comes out of the study, it will sensitize twenty-eight federal agencies to the fact that innovation is an important part of our economy and should be considered in all of their actions. "If that is accomplished," Baruch remarked, "I can rest in peace."

Robert Massey, of Progress Management Services, commented that the discussion has implied that innovation is the result of R&D investment and entrepreneurship. If one measures innovation by success in the marketplace, which is highly influenced by cost and reliability of the products, it should be noted that experience in Japan and many American companies has shown that product quality and the steepness of the cost reduction learning curve are highly influenced by the numbers of microinnovations brought about by rank-and-file workers. Dr. Sidney Harmon, of Harmon International Industries, and currently Under Secretary of Commerce, is one of the leaders in the U.S. in harnessing the heads and hearts of the worker to reduce product cost and improve product quality. Baruch replied that those working on the industrial innovation study are very aware of the impact of worker participation upon the innovative process, an area Dr. Harmon will be looking at closely. That is one of the significant reasons labor participation has been invited into the public portion of the study.

John Stewart, of the Senate Committee on Commerce, Science and Transportation, noted that in our federal system there is oftentimes a great intermingling of responsibilities among the various levels of government. He questioned Lockwood whether in his dealings with forty-two government agencies at the state and national level there had been any perceptible difference in how they operated and in their understanding of, and responsiveness to, his problems, and in the competence they brought to their task. Conventional wisdom suggests that people at the state and local level would be closer to the problems, might understand them better, and would thus be more sympathetic. Lockwood replied that by and large there are good, sensitive, sympathetic people at all levels of government. The problem is not competency, but just the great amount of work they are given to do by the voters. Trouble comes when they must deal with something new that is not understood. Laws and regulations designed for something entirely different apply and one must spend enormous amounts of time in educating well-meaning government people. There is one exception: OSHA. OSHA has by far gone beyond its intended purpose, and they are the only ones in government who have been truly vindictive. When they came to inspect Lockwood's business, they assumed he was guilty since he was a businessman.

Lockwood commented on the problem of the lack of capital availability for new technological development. Bills have been submitted in both houses of Congress to revert the capital gains tax back to where it was in 1969. That would provide a tremendous stimulus for small business capital formation. Forgetting the equity issues, the reduction would direct the cash flow to small businesses. The Securities and Exchange Commission is holding hearings throughout the country to look at the impact its regulations are having on small business capital acquisition. It is taking an objective look into determining whether in the interest of preventing fraud the door has been slammed on small companies that seek capital. Another major influence on capital availability, which is going in the wrong direction, is the Employee Retirement Income Security Act (ERISA). Congress, particularly Senator Javits, doesn't understand what the retirement programs under ERISA have done to the flow of savings. Specific legislation is not the answer, however; it would only compound the problem.

Lawrence Rhoades, with the American Sociological Association, commented that in both days' sessions everyone talked about social issues. However, the only social science that was mentioned frequently was economics. Others, such as political science, psychology, sociology, and anthropology were ignored. As one listened to the arguments, particularly during the present session, it would seem useful to look at basic research in the social sciences, particularly as it relates to social change and to the development and implementation of normative (regulatory) systems. One would hope that discussion of innovation in industry would draw on social as well as natural and physical sciences. In addition to material technology there is what is known as social technology. In this session the argument is about whether social technology, in the form of regulations, is either hindering or promoting industrial innovation and societal well-being. Baruch replied that the social sciences are being considered in the innovation study. Anybody concerned with the process of innovation has read Rogers' work on the diffusion of innovation among many others. Much of the structure of the innovation study comes from a caution by Amati Etzioni, a social scientist, who says that when one looks at the development of options and the development of decision points, one should focus on the maleable variables. In the innovation study the focus will be on such variables. While being equally important to the innovation process, many variables that deal with attitudes in industry, and the structure of industry, are not maleable from the government end.

Mosher added that the debate over regulation will forever be an evolving process of accomodation, the swinging back and forth that is primarily the political process. Roberts noted that because social regulations stem from the political process, efforts to deal with them are more and more in the political arena. Our political system is an area where scientists, engineers, and businessmen must become more sophisticated. Mosher responded that such sophistication is extremely important. As a long time member of the congressional process he knows that scientists, engineers, businessmen, and executives have not been as effective as they should be, either as a class or as individuals, in educating, informing, and influencing (in the best sense) members of Congress.

Bartlett commented that this session had the topic, "R&D and the Economy." Theoretically the session was to look at the relationship between R&D and economic development in the U.S. However, the group was almost unavoidably drawn not into a discussion of R&D problems--these were simply the first paragraph--but into problems that are fundamentally political, philosophical, and economic. Trying to see the relationship between basic research, high technology, and our economic life quickly transcended the concerns one would have expected in this sort of meeting. An example was how Lockwood, in his prepared remarks, quoted Solzhenitsyn, an abstract way to get at problems in science and technology. One is left with the impression that our culture is at a philosophical crossroads. The trail which led us to them can be described in many ways. The result is a society unsure of what its values will be. A clear example is the present conflict based on concern for the environment. Another example is the notion of government as a defensive rather than a promoting mechanism. Wide-ranging problems such as the role of consumption are ultimately involved in considerations of the subject of innovation. Americans expect to consume all the production we can afford. When that high consumption is put on top of high defense expenditures, little is left over for the capital formation necessary to innovation. The problem is ultimately a philosophical one, a values' issue. The issues seem to transcend influences by government programs and by applications of science and technology.

Luncheon Address

J. J. Pickle

U.S. House of Representatives

Economists often do not agree on much of anything, but they do agree that innovation usually results in economic progress. Businessmen know that developing new products and inventing cheaper and better ways of making existing products are tantamount to survival.

The evidence of this surrounds us. If we look just at one example, the computer, we see not only a changed lifestyle but a geometric widening of man's scope of knowledge. We see a whole new industry opening as many jobs as the automobile did a generation earlier. And we see a range of products from sophisticated satellites to pocket calculators and digital watches that are a direct result of research activity and the creative use by businesses of that research.

The economic history of the United States is in large part the story of significant innovations by scientists and businessmen and the resulting benefits to consumers. This is something everyone believes at least in theory. Innovation is part of the American character. But it is not always easy to shape government policy so that it boosts this great American asset.

We went through a period recently where people looked at the results of technology--the atom bomb, polluted skies, oil in the oceans, streams, and lakes without fish or other life, ticky tacky housing, and piles of garbage--and the scientist and technologist found himself a somewhat suspect figure.

Fortunately that time is past, for many of our most pressing social and economic problems can be solved only by development of new technology.

One vestige of this controversy remains troublesome today, and we should all be aware of it and attempt to find some solution to it. That is the feeling that big concerns are synonymous with rip-off concerns. The big is bad syndrome was quite evident, for instance, in the debate over several years before the Congress passed loan guarantees to encourage industry to develop oil shale, biomass and other domestic resources into synthetic fuels, including a vote of 193-192 in one round of the debate not to consider the proposal in the House at all. It is evident again in the rhetoric surrounding the debate over the efforts to develop satellite solar power--a bill now slated to be brought before the House this Friday. The big is bad syndrome has also posed a major stumbling block in seeking compromises on the energy legislation.

For the past year the Congress has been struggling toward enactment of major energy legislation designed mainly to encourage energy conservation. The debate sometimes obscures the fact that this bill will not solve the energy crisis. The development of new energy sources is the only viable long-term solution to our energy shortage. We need fusion power. We need to boost rockets with laser engines instead of liquid fuel engines. Or perhaps we will need to develop things which are today only remote ideas in the minds of you and your colleagues.

We can't simply wait for that day, however. In the shorter run we will call on you to develop techniques for energy conservation--for achieving the same standard of living with less energy--and the oil industry will need help in finding and extracting oil and gas more efficiently. We will call on you, too, to develop production methods that do not pollute.

Many economists believe that the key even to reducing inflation is to improve productivity. A much touted--but little appreciated and even less applied--way to improve productivity is to do more research and development. Expenditures on R&D yield a 33 percent rate of return--a powerful force for productivity. But as a percentage of gross national product, government, industry and university spending on R&D has declined from 2.9 percent in 1969 to 2.2 percent this year.

It seems when the budget gets tight one of the easiest places to cut is R&D. But the economics of this time demand massive investments in basic resources--energy, transportation, water, and the like. This fact is growing more and more clear, I think, and we are going to have to redirect our federal efforts more in that direction. That's not as easy as it seems. In the federal budget you are up against tough odds. For instance, about one third of our federal budget now goes for programs for our aged. This means you may not be competing for funds against unpopular items like welfare or foreign aid so much as you are competing against caring for old people or education programs for our youth or nutrition programs for pregnant mothers or things like this.

Federal support of R&D faces an additional burden in that, with the possible exception of a few agencies like the National Science Foundation, it is not equipped to deal with the small businesses and individuals who are so very important to R&D efforts. I have had some dealings with the Department of Energy where I think they were as frustrated as I that they simply couldn't deal well with an entity smaller than Exxon or Dupont.

Federal tax policy could play a decisive role in encouraging more R&D. It can do so within the broad framework, and it can also--with some modifications--deal easily with the small business and the individual.

Presently, there is a significant tax incentive to encourage businesses to conduct research and development. Under Section 174 of the Internal Revenue Code, most research expenditures can be written off in the year incurred, rather than amortized over several years as is the case with most other capital expenditures. The current provision permitting businesses to deduct research expenditures immediately, however, does not apply to the acquisition or improvement of depreciable property. Congress should consider expanding Section 174 to give more favorable treatment to depreciable property used for research and development.

I have an amendment pending to the President's recent tax proposals to substitute a special research and development investment tax credit of twenty percent for the normal ten percent credit. This special investment tax credit would apply only for capital investment in R&D by research firms with total business receipts of less than $6 million per year. The amendment phases the credit down to twelve percent for those earning $10 million per year.

I also have a second amendment to qualify capital investment in assets with a lifetime of only five years or longer for the full investment tax credit, and for half the credit for assets with useful lifetimes of three to five years. This, too, would apply only to R&D businesses with receipts of $10 million or less.

Besides expanding the investment tax credit, there is a lot of support now for lowering taxes on capital gains. This would help new companies and high technology companies raise equity capital.

I am not sure, frankly, what is going to happen in either of these fields. They are very much tied up with the current impasse over the President's tax bill in the House Ways and Means Committee. If the tax bill folds, I will have to look for another way to enact the proposals I have made regarding the investment tax credit. Also, Congressman Steiger of Wisconsin has proposed lowering the capital gains tax from its present level of up to fifty percent back to the 1969 level of 25 percent. This is hotly opposed by more liberal members of the Committee and by the Administration. Congressman Jones of Oklahoma has proposed a thirty-five percent compromise level as part of a total compromise package. But there are so many views and issues and side issues intertwined in the negotiations among committee members that it is difficult to see what--if anything--may finally be agreed upon. I was quoted several weeks ago saying it looked to me like the whole bill was rolling headlong down the hill into the creek of confusion--and that has proved an unfortunately prophetic statement.

We need to look beyond the current tax bill at other issues, too. In creating a better climate for R&D we also need to address having more liberal deductions of capital losses for risky R&D investment. And we need to get a better understanding of the long range impact of our tax treatment of U.S. earnings abroad. A major incentive for American business to innovate is the prospect of earning profits abroad with new technology. That could be encouraged by liberalizing the tax treatment of income from exports and from income earned abroad by U.S. citizens. Some might argue we should avoid this approach, however, because this country would not directly benefit from the new jobs.

Tax policy can affect private R&D in several ways--for good or for bad. Congress must pay better attention to the effects of tax policy on this field.

Many people in and out of Congress think of science as tinkering with gadgets--or they think of it as unlocking mysteries of the universe. Both views, while true, are blind to the bedrock role that science plays in our economic well being.

I am not comfortable associating myself with the view that research and development in this country has passed its peak years--the years of NASA and Vietnam. True, those were golden years for research fields that were in large measure thrust upon us. But other critical problems will be thrust upon our society or any society. The energy issue alone has greater potential for research and development than Apollo and Vietnam combined. And on the heels of energy come problems in transportation, water resources, material shortages, and other basic resources and needs of our society that must be addressed if we are to maintain a reasonable world and a reasonable style of life. All that is left to be determined is the scope of our involvement and our determination. And this does not need to wait ten years. It needs to be talked about, admitted, and tackled now. You know this, but you yourselves must take that hardnosed economic approach and convince your own congressmen and senators that your views should be credited. Tell them to support the Pickle amendment and other helpful programs. You yourselves must study the issue and give us your suggestions on how best to enable you to carry us through the needs of the next decades. Don't wait for the sun to bake your biscuits for you. I hope you will knock on our doors--maybe not as much as the abortion or the gun control people--but enough to get our attention and get the job done.

Concluding Remarks

William D. Carey

Executive Officer, AAAS

We have traversed a great deal of ground in these two days, and at high speed. It's too soon to reach a perspective on the effects of this third AAAS Colloquium on R&D Policy, but my sense of it is that we did substantially what we hoped to do. And that was to surface some major current policy issues concerning R&D, in an arena of debate and analysis involving the concerned parties: the Administration, the Congress, industry, the non-profit sector, and the universities. We were again able to set a framework with the analytic report by Shapley and Phillips. If we have not answered the policy questions, at least we seem to have defined and illuminated them.

Today's Post gives one account of what occurred here yesterday, while the Times gives another. The Post said that the only optimism was uttered by--of all people--me. Not so. I think we haven't been holding a funeral at all. The news is better than that. My own impressions are that on the government's side, the system of policy management for R&D is beginning to look impressive. There is, I think, an unmistakable reaching for more architecture of science and technology policy, a blending of science policy with economic and budget policies, and a visible tilt towards multiyear planning strategies. The field of indicators is being developed, not as an abstract numbers' exercise, but as a process linked directly to policy management. This is what I think that I see, and I like it. It doesn't mean that public policy for science and technology is settled, nor complete, nor that there is consensus about it. But I think it means that public policymakers are trying very hard to cope, and that is worth a lot.

The White House study project on the problems of technological innovation is an important initiative, and it will need all the help we can give it. I can foresee future AAAS colloquia structured around the outputs of this project. But I think we should be cautious and realistic in our expectations, because an interagency committee study is not necessarily the shortest route from a problem to a solution. Moreoever, the results of the study will reach the President, under the best of circumstances, in the late summer or early fall of 1979. Let's assume that policy changes are decided and sent to Congress early in 1980, covering the spectrum from funding to tax incentives, patent policy, cost principles, and procurement and institutional changes. These proposals will go to a range of legislative committees and hearings. Suppose the Congress acts by 1982. On this basis, we will be in the mid-1980s before the changes take a grip on the R&D process, and conceivably beyond the life expectancy of the present Administration. The long lead times for technological innovation, and the lead times for policy innovation, are not so very different, after all.

The other major policy variable that came to light was the very candid statement from OMB that the 1980 budget is going to be dressed in a straitjacket because of anti-inflation policy. Everyone, said Bow Cutter, will have to accept a share of austerity. That is fair, but it could mean that the President's excellent R&D policy intentions as reflected in his 1979 budget may have to be curtailed, stretched out, or scaled down within the short space of one fiscal year. It spells another wave of uncertainty for R&D, even though at the same time OMB is heading towards three-year budget commitments which are designed to increase certainty.

So, what I see is a classic example of government struggling creditably towards a better handle on policy management in the area of R&D, against very tough discontinuities. The first clues will be reflected in the OMB's planning guidance to the agencies over the next couple of weeks. But if that is the bad news, the good news is the disposition of the Administration towards R&D as good investment and good economics. Science policy, over the past three years, has reached higher ground and I don't believe any of this ground will be lost.

AAAS has been complimented by the generous participation of first-rate speakers and panelists in this Colloquium. My thanks go to all of them, to the AAAS staff, to the Committee on Science, Engineering and Public Policy, and to the Sloan Foundation. I hope that the news of what AAAS is trying to do in science policy will travel well and travel far, and that next year, somehow, we will manage to produce AAAS Report IV and another solid Colloquium, because as we say these days in Washington, "the opera isn't over 'til the fat lady sings."

APPENDIX

Colloquium Participants

Loren Abdulezer
Polytechnic Institute of New York

Arthur H. Albrecht
3M Company

P. W. Allderdia
Memorial University

Harvey Alperin
Naval Surface Weapons Center

Richard L. Altman
Pratt & Whitney Aircraft

Irving Antin
Southern Illinois University

Albert Ardale
New England Nuclear

D. R. Baldwin
American Psychological Association

J. Robert Barlow
Cornell University

Robert Barnum
Exxon Research

Ronald E. Barr
University of Missouri

Alden S. Bean
National Science Foundation

Charles Beer
United States Department of Agriculture

James E. Belton
TRW Systems & Energy

Joseph W. Berg, Jr.
National Academy of Sciences

William Bevan
Duke University

Lyle Bighley
Marion Laboratory

Jacob F. Blackburn
State Department

William Boesman
Library of Congress

A. Freeman Bradley
University of California

Albert Bridgewater
National Science Foundation

Molly C. Broad
Syracuse University

Kenneth Brown
General Accounting Office

William F. Brown
Department of Transportation

Philip M. Burgess
Western Governor's Policy Office

Herbert Burklund
Sherago Associates

Beth Burnam

Barbara A. Burns
National Science Foundation

Grace G. Burns
National Bureau of Standards

Donald E. Buzzelli
National Science Foundation

Neil Campbell
Lab Products, Inc.

Jean Cantacuzene
French Embassy

John D. Caplan
General Motors Research Labs

Luigi Cappugi
Fiat Research Center

Giacomo Carbonara
Fiat Research Center

James E. Carpenter
National Science Foundation

Charles E. Cathey
Department of Energy

Richard H. Chapman
U.S. Army Engineers

Stanley H. Charap
Carnegie-Mellon Institute

Dick Charles
Sherago Associates

George S. Cherniak
TRW Systems & Energy

John R. Chirichiello
National Science Foundation

Craig J. Church

Howard Clark
Senate Committee on Commerce,
Science & Transportation

Jack L. Cochran
University of Michigan

Parker L. Coddington
Harvard University

Michael L. Cohen
TRW Energy Systems Group

Steven Cohn
National Science Foundation

Michele T. Cole
University of Pittsburgh

Martin J. Cooper
National Science Foundation

H. Roberts Coward
Institute for Scientific
Information

Gordon G. Cross
The Standard Oil Co. (Ohio)

John C. Crowley
Association of American
Universities

Charles G. Culver
National Bureau of Standards

Robert S. Cutler
National Science Foundation

Roslyn Dauber
Office of Technology Assessment

Ruth M. Davis
Office of the Secretary of
Defense

Donald E. Day
General Accounting Office

Marietta DeBoever
SRI International

John DeJong
Office of Management & Budget

Enrique M. del Campo

David W. Dorn
Lawrence Livermore Lab

David Douglas
Gould Inc.

Mary Anne Doyle
Regis College

Howard F. Drew
The Proctor & Gamble Company

Thomas Duchesneau
National Science Foundation

Edgar Durbin
BDM Corporation

Paul A. Eichorn
Philip Morris USA

Lennart Elg
Swedish Embassy

J. Emptoz
French Scientific Mission

Scott E. Evenbeck
Indiana University

Charles E. Falk
National Science Foundation

Andrew D. Farrell
IIT Research Institute

H. Scott Finer
Office of Technology Assessment

Robert C. Fitzpatrick
State University of New York

Steven Flajser
Senate Committee on Commerce, Science & Transportation

Robert Fleishcer
The Graylock Center

Penny Foster
National Science Foundation

Marvin R. Frederick
BF Goodrich Research & Development Center

Debra Freedman
Polytechnic Institute of New York

Norman Friedman
National Science Foundation

Osmund T. Fundingsland
General Accounting Office

Herbert Fusfeld
Kennecott Copper Corporation

John L. Gable
Federal Aviation Administration

David H. Garber
University of Minnesota

Arthur Gerstenfeld
Worcester Polytechnic Institute

Charles H. Gold
Northwestern University

Joel Goldhar
National Research Council

Leon Green, Jr.
General Atomic Company

Ann H. Greenberg
New York University

James L. Gumnick
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Walter A. Hahn
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Robert B. Hall
General Accounting Office

John R. Hansen
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Martha Hatcher
Gainesville Junior College

William F. Hederman
Rand Corporation

William G. Herrold
Institute of Electrical & Electronics Engineers

Henry Hertzfeld
National Aeronautics & Space Administration

Klaus Hesse
Embassy of the German Democratic Republic

Peter L. M. Heydemann
National Bureau of Standards

James Hochn
National Science Foundation

Thomas Hogan
National Science Foundation

John L. Hoover
Argonne National Laboratory

John H. Hopper
Kellogg Company

Emanuel Horowitz
National Bureau of Standards

Frank L. Huband
National Science Foundation

Carrie J. Hunter

Barney D. Hunts
The Singer Company

Elmuntasser Hussein
Libyan Embassy

Thomas E. Jenkins
University of California

George P. Johnson
National Science Foundation

Willis Johnson
Wabash College

Lewis P. Jones
National Science Foundation

Merrill Jordan
Cabot Corporation

Thomas Jones
Massachusetts Institute of Technology

John W. Kalas

Bruce P. Kelly
McKinsey & Company, Inc.

Charles W. Kent

Sheila Kern
SRI International

Matthew J. Kerper

Bernard Khoury
Educational Testing Service

Charles V. Kidd
George Washington Library

Carole E. Kitti
National Science Foundation

Kenneth A. Klivington
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Ronald M. Konkel
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Robert P. Koontz
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Stanley Kramer
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Thomas R. Kramer
House Committee on Science & Technology

Lawrence M. Kushner
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Walter N. Lambert
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William T. Lankford
U.S. Steel Corporation

Donald L. Lansing
National Aeronautics & Space Administration

Richard B. LeBaron
General Accounting Office

Harry P. Leckie
Inland Steel Company

Rene J. A. Levesque
Universite de Montreal

Milton Lieberman
Research Triangle Institute

James L. Liverman
Department of Energy

John A. Lockwood
University of New Hampshire

John M. Logsdon
The George Washington University

Alexander London
Weizmann Institute of Science & Columbia University

Beverly Lovelady
General Accounting Office

Robert P. Lowman
American Psychological Association

Barbara Lucas
National Science Foundation

Edward MacCordy
Washington University

Lowell Magner
E.I. du Pont de Nemours & Co.

Sonya Mallinoff
National Science Foundation

Dillon Mapother
University of Illinois

Robert J. Massey
Progress Management Services

Paul Maxwell
Senate Committee on Commerce, Science & Transportation

Robert L. Maxwell
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